CONSERVATIVE SURGERY IN TUMORS OF BONE

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A DVANCES in the treatment of bone tumors have kept pace with progress in other fields of medical research. The history of the treatment of tumors affecting the skeletal system reveals that in earlier times, amputation was the only method available. This was practiced more or less indiscriminately for both benign and malignant tumors.

The valuable information gained by roentgenographic and histologic studies, as well as by chemical investigations of serum calcium, phosphorus and phosphatase, has made possible a far more accurate survey of each individual case. Consequently, we now know that in certain conditions, radiation alone or combined with surgery gives better results than were hitherto obtainable.

It is my intention to consider here only those cases that lend themselves to conservative surgical treatment. No mention will be made of the others that still require amputation, or those that are best treated by radiation.

TYPES SUITABLE FOR CONSERVATIVE SURGERY

Bone Cyst. Solitary Osteitis Fibrosa Cystica.—This condition is closely akin to that of giant cell tumor. It differs chiefly in the age incidence. Cysts of bone occur in young people before the epiphyses have closed, whereas, giant cell tumors affect young adults after epiphseal closure and are sometimes seen up to the age of 45.

The surgical treatment of bone cyst is uniformly successful and is preferred because of the fact that radiation of the adjacent growth center may interfere with the normal growth of bone, and produce a shortening of the extremity. The technic is identical to that employed for giant cell tumor.

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Fig. 1. Aneurysmal giant cell tumor of fourth metacarpal (case 1).

Fig. 2. Same case after curettage and implantation of bone transplants from tibia.

Giant Cell Tumor in Accessible Locations.—Time will not permit of a discussion of the relative merits of radiation versus surgery for giant cell tumor of bone. Both methods have their advocates; and satisfactory results are obtainable by each. In general, we prefer surgery for accessible lesions. *For example:* for tumors situated in the lower femur or upper tibia, curettage is suitable; while for lesions of the upper fibula, rib or metatarsal, resection is more certain to give a lasting cure. If the area of destruction is extensive, implantation of a massive bone graft or filling the cavity with bone chips is recommended.

Fig. 3. Same case 6 months after operation.

The technic of curettage is briefly, as follows: The skin preparation is carried out as scrupulously as for any open bone operation. Provision should be made for a transfusion immediately after the operation if there has been an undue loss of blood. Under general anesthesia, and using a tourniquet, the skin is incised over the tumor-bearing portion of the bone. In selecting the site, care should be taken to avoid the adjacent joint cavity. The incision passes down to the periosteum, splitting the muscle rather than incising it whenever possible. The periosteum is divided and stripped back to expose the cortex which is to be removed to unroof the cavity and give access to the tumor. A rectangular window is then made either by an osteotome or a motor saw. After enlarging the opening by ron-

geur, curettage under direct vision aided by palpation and the Cameron light, is rapidly performed. All particles of tumor tissue must be removed. Repeated flushing of the cavity with Dakin's solution is of advantage. The interior of the cavity is thoroughly swabbed with saturated solution of zinc chloride or with phenol followed by alcohol. The caustic is allowed to come in contact with the walls of the cavity for only about a minute; it is then flushed away by flooding with Dakin's solution. Thereafter, the periosteum, muscles and fascia, and the skin are accurately closed with interrupted sutures of fine silk. Under no circumstances should
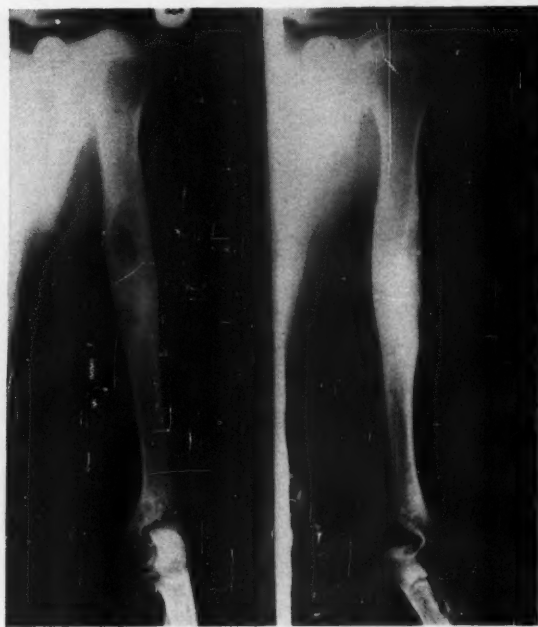

Fig. 4. Central chondroma of humerus—borderline malignancy—after three failures to control by curettage (case 2).

drains or packing be used. The tourniquet is removed and a snug bandage applied over a bulky gauze and sheet-wadding dressing held firmly by leg-rolls of gauze. Plaster is used for complete immobilization. The dressings should generally not be disturbed for the first ten or twelve days.

Prevention of pathologic fracture is imperative, and in lesions of weight-bearing bones, caliper splints may be needed until roentgenograms reveal a sufficient regeneration of bone. Every effort to restore joint- and muscle-function should be made during the convalescent period.
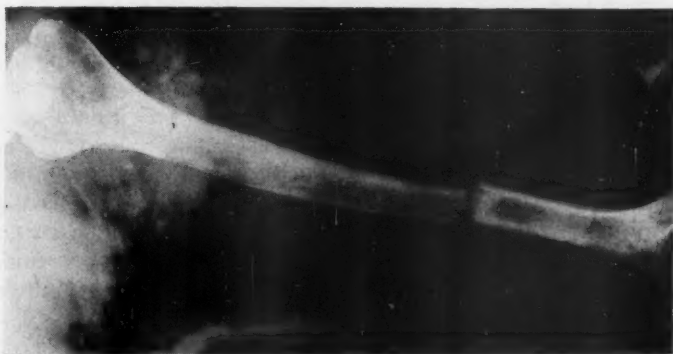
Fig. 5. Same case after segmental resection and massive tibial transplant to replace defect.

Fig. 6. Same case 18 months after operation, showing complete consolidation of the transplant. Patient has good function, pursues former occupation as typist, and is still free of disease 4 years postoperative.

Central Chondroma—Myxoma.—Central chondroma is a not uncommon benign tumor and, like the far more rare pure myxoma of bone, tends to undergo malignant degeneration. It should therefore be eradicated while still benign. It requires the most thorough extirpation for it inevitably recurs if not completely removed. Case 2 illustrates this point and serves as an example of a successful seg-

mental resection of a long bone with substitution of a massive bone transplant after several unsuccessful attempts had been made to remove the tumor by curettage.

When central chondroma occurs in the phalanges, it does not undergo malignant degeneration and is an exceedingly slowly-growing process. Cases have been seen in which successive pathologic fractures from comparatively mild trauma have healed with only slight deformity. In this type, the same measures are employed as are used for cyst and giant cell tumor. Success depends upon removal of every particle of tumor tissue by a thorough curettage followed by cauterization.

Osteogenic Sarcoma.—While most osteogenic sarcomas call for amputation, there are infrequently encountered cases which, because of their low-grade malignancy or because of some unusual anatomic considerations, are suitable for less radical surgery. This is particularly true of parosteal or pedunculated growths or those developing on pre-existing chondromas, or less frequently, on a posttraumatic myositis ossificans. Exceptional cases of chondroma or myxoma bordering on malignancy (chondromyxosarcoma) are encountered which may lend themselves to resection and massive bone graft (fig. 4).

If the lesion occurs in a bone that can be resected in whole or in part without loss of function of the extremity, this method may be employed. Examples are: total or partial resection of the scapula (figs. 11, 12 and 13), and resection of the upper portion of the fibula (figs. 14 and 15). Judgment based on experience is essential for the selection of cases to be treated by these less radical measures. Figures 16 and 17 illustrate the use of a partial amputation of the hand for osteogenic sarcoma of a phalanx. This is an exceedingly unusual location for a primary malignant bone tumor.

Endothelioma (Ewing's Sarcoma).—It is most unusual to encounter a case of this type in which conservative surgery is justified, although, results by radical amputation with or without radiation therapy, seldom yield a five-year survival. Figures 18 and 19 illustrate the use of total scapulectomy in a child with endothelioma. Although widespread metastases ultimately occurred and proved fatal, there was never a local or regional recurrence. It seems evident that the procedure which preserved the upper extremity accomplished all that could have been achieved by interscapulothoracic amputation.

The following are a few examples of cases of bone tumor of various types and localities that have lent themselves to conservative surgery:

CASE 1.—E.S.B., female, aged 31, was admitted to the Memorial Hospital on Dec. 27, 1939 with a history of having sustained two previous pathologic fractures of the fourth metacarpal. Roentgenograms revealed an expansile osteolytic lesion of the entire head and shaft. An operation, performed on December 29, consisted of curettage of cavity, and tibial transplant. The wound healed per primam.

Pathologic diagnosis: Angiomatous giant cell tumor.

When last seen, eight months after the operation, the patient was in excellent condition with no disability of the hand (figs. 1 and 2).

CASE 2.—A. C., female, age 27, was admitted to the Memorial Hospital on Sept. 13, 1930 with a history of intermittent pain over a period of four years. The first roentgenographic examination, made three months prior to her admission, revealed a "cystic area in the middle third of the left humerus." There had been no previous surgical or radiation therapy. Local examination revealed a smooth, tender, spindle-shaped swelling of bone.

Following a curettage on Sept. 25, 1930, a pathologic diagnosis of central chondroma was made. A recurrence was noted ten months later, and a second curettage was done on July 23, 1931, following which the pathologist reported: "Atypical mucinous granulations, chronic osteis, callous."

The patient remained practically symptom-free for eight years, at the end of which time, the pain recurred. Roentgenograms revealed reactivity in the mid-humerus. She was readmitted to the hospital on June 4, 1934, for a third operation which consisted of an extensive exposure of the tumor-bearing area, and curettage.

Pathologic diagnosis: Degenerating chondromyxoma.

The wound, as usual, healed per primam.

The patient again remained symptom-free for two and one-half years, when because of pain and the roentgenographic evidence of a recurrence, it was decided that a segmental resection of the mid-portion of the humerus was indicated. The fourth operation (Jan. 18, 1936) consisted of resection of the middle third of the humerus with substitution of a massive tibial transplant for the defect (see fig. 5). Following the operation, splenic extract was administered orally. The arm was immobilized with plaster shoulder spicas, changed occasionally, for the next seven months. Thereafter, physiotherapy was instituted and a special brace was made to support the limb. Roentgenograms revealed solid union of the transplant to the upper and lower portions (see fig. 6).

The patient was back at her work as a typist one year after the fourth operation, and she has worked steadily for the succeeding three years. There has been no further return of the disease.

CASE 3.—P. B., male, aged 39, was admitted to the Memorial Hospital on Oct. 15, 1940, with a history of having sustained a crushing injury to the tip of his right thumb four years previously. The pain, swelling and ecchymosis subsided but the thumb remained enlarged. Six weeks prior to his admission, he struck the tip of the same thumb.

Roentgenograms revealed a central osteolytic expansile tumor of the terminal phalanx with pathologic fracture (fig. 7).

Operation on Oct. 16, 1940 consisted of curettage and the introduction of tibial transplants in the cavity. The wound healed per primam (fig. 8).

Pathologic diagnosis: Central chondromyxoma.

Examination on Feb. 11, 1941 showed a practically normal contour of the thumb; there was no pain or disability; roentgenograms revealed healing.

Fig. 7. Central chondroma of terminal phalanx of thumb (case 3).
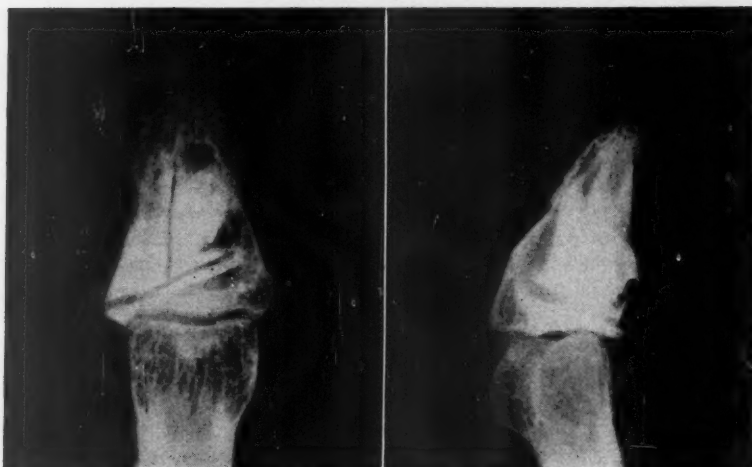

Fig. 8. Same case after curettage and bone transplant from tibia.

CASE 4.—H. B., female, aged 38, was admitted to the Memorial Hospital on April 4, 1937, with a history of swelling on the anterolateral aspect of the lower left femur, of two years' duration. No attention had been paid to it until one year previously when mild pain caused the patient to consult a physician. He advised a roentgenographic examination but this was deferred until three weeks prior to her admission to the hospital. The films revealed a bone

Fig. 9. Parosteal osteogenic sarcoma of femur (case 4).

Fig. 10. Same case 9 months after excision. No recurrence 3 years and 11 months later.

tumor (see fig. 9). A biopsy was performed and a diagnosis of osteogenic sarcoma was made.

Examination on her admission to the Memorial Hospital revealed a smooth, ovoid swelling, measuring 8 by 9 cm., firm and non-tender, over which a well-healed, recent scar, 7 cm. long, was present. Flexion was limited by 15 degrees, but extension was unrestricted.

At operation on April 5, 1937, performed under general anesthesia, the tumor was completely excised, and the portion of the femur from which it sprang, was saucerized and cauterized with zinc chloride solution. The wound was closed in layers; it healed per primam.

Pathologic diagnosis: Chondrosarcoma of low-grade malignancy (B.S.R. No. 2249).

The patient's convalescence and subsequent course was uneventful. When last seen on Oct. 30, 1940 or three and one-half years after operation, she had full range of motion with no disability or restriction of activities. There was no evidence of a recurrence or metastasis (fig. 10).
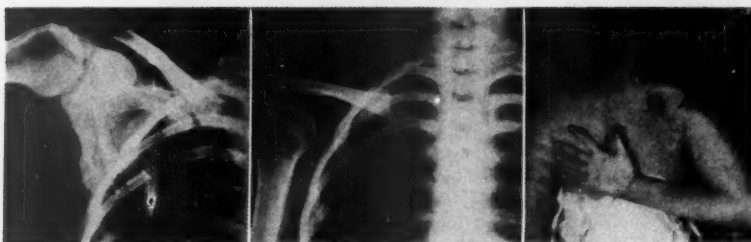

Fig. 11. Chondromyxosarcoma of inferior angle and axillary border of scapula (case 5).
Fig. 12. Same case after total excision of scapula.
Fig. 13. Same case one year later, showing patient's ability to use upper extremity.

CASE 5.—A. S., a white female, aged 32 years, was admitted to the hospital with a diagnosis of chondromyxosarcoma of the scapula, recurrent. A subtotal excision of the scapula was performed on March 16, 1935, following which there was a prompt recurrence, and a total excision of the scapula was performed on Aug. 27, 1935 (fig. 12).

Pathologic diagnosis: Chondromyxosarcoma.

Examination one year after the second operation showed the patient to have excellent anatomic and functional results. She was still well and free of recurrence when last traced, five years after the second operation (fig. 13).

CASE 6.—W. B., male, aged 14, was admitted to the Memorial Hospital on Sept. 14, 1938 with the following history: One month prior to admission he sustained a football injury. While there were no external signs of the blow, one week later the upper part of the calf became swollen, tender and showed increased heat; temperature 100°. After a week's rest in bed all symptoms and signs disappeared. There were four similar episodes occurring at two, three and four-month intervals; all were characterized by pain, swelling, local heat and slight fever. Roentgenograms taken just prior to admission showed a "tumor in the upper portion of the fibula."

Physical examination disclosed no appreciable swelling, tenderness or impairment of motion at the knee. Further roentgenograms revealed an expansile osteolytic lesion in the head of the fibula. An aspiration biopsy yielded no information. A surgical biopsy was then performed from which a diagnosis of endothelioma was made. The wound healed per primam.

High-voltage roentgen therapy was given using 4 portals for a total of 5400 r (air), thus delivering a tumor dose of 4000 r. The patient was then discharged. He was readmitted to the hospital on Nov. 8, 1938 for a course of toxin treatment (Coley's); 11 injections in all were given. At the same time, a second operation was performed consisting of resection of the upper fourth of the fibula and a portion of the tibia adjacent to the tibiofibular articulation (figs. 14 and 15).

Fig. 14. Sarcoma of fibula (case 6).
Fig. 15. Same case 7 months after operation. Patient well 2¼ years after resection.

Pathologic findings: No residual tissue found in resected portion of fibula. The wound healed and he was discharged on Dec. 7, 1938.

Examination on Feb. 26, 1941 showed the patient in satisfactory condition with no evidence of recurrence or metastases. With the exception of footdrop—as a result of peroneal nerve injury—the patient has no resulting disability nor interference with his school activities.

CASE 7.—W. C., a male, aged 30, was admitted to the Memorial Hospital on Feb. 10, 1937, with a history of having injured the metacarpophalangeal region of the right 4th finger, three months previously while at work. Simple treatment for a "bruise" was carried out but a steady, slow increase in the

Fig. 16. Post-traumatic osteogenic sarcoma of proximal phalanx, apparently on a basis of myositis ossificans (case 7).

Note: Osteogenic sarcoma involving a phalanx is exceedingly rare. There is no case on record in the Bone Sarcoma Registry.

Fig. 17. Same case 1 year after partial resection of hand. Patient, a bus driver, is working, and is free of disease 4 years after operation.

size of the base of the fifth finger was noted. Pain was felt, especially when the hand was in a dependent position. Five weeks after the accident, a web incision was made but no pus or fluid was obtained. Roentgenograms were
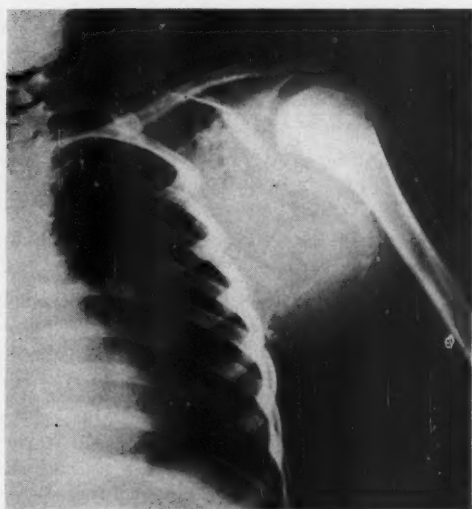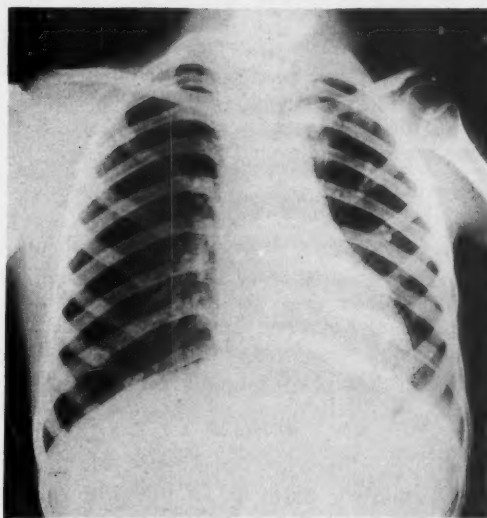
Fig. 18. Endothelioma of scapula (case 8).

Fig. 19. Same case after total excision.

taken on January 13 and January 30. The patient was then admitted to another hospital where tissue was obtained for histologic study. Meanwhile the swelling remained apparently unchanged, although the throbbing pain persisted.

Pathologic diagnosis (biopsy specimen): Chronic productive osteitis.

Roentgenograms revealed a productive growth of bone arising from the proximal phalanx of the fifth finger.

Operation on Feb. 16, 1937 consisted of amputation (following an exploration of the tumor-bearing area) of the fourth and fifth fingers and most of their metacarpal bones (see fig. 17). The wound healed per primam.

Pathologic findings: Osteogenic sarcoma, low-grade, probably non-metastasizing, and probably on a basis of myositis ossificans.

The patient's subsequent course was satisfactory; he was able to drive a bus for several years. When last seen on Jan. 27, 1941 or four years after the operation, he was still in excellent condition.

CASE 8.—J. V., male, aged 9, was admitted to the Memorial Hospital on June 24, 1939, with an indefinite history of injury; *viz:* in May, 1938, he had fallen down stairs. One month later, his mother discovered a lump in the left scapular region. Two months later, roentgenograms were made which were said to be negative. In January, 1939, because of a steady increase in the size of the swelling, further films were taken, and these were said to be suggestive. A five-weeks course of osteopathic treatment was given. In May, 1939, after another injury, the swelling increased more rapidly, and further roentgenograms at this time revealed a malignant tumor of the scapula.

Examination on his admission to the Memorial Hospital disclosed a large tumor of the left scapula measuring 20 by 10 by 10 cm. It was tense but not tender, and showed increased surface temperature. The movements of the upper extremity showed very little restriction. Roentgenograms revealed a remarkable involvement of nearly the whole scapula in an expansile tumor, mainly osteolytic (see fig. 18). Following an aspiration biopsy a diagnosis of malignant tumor, probably osteogenic, sarcoma, was made.

A total excision of the scapula was performed on Aug. 28, 1939, following which, the wound healed per primam (fig. 19).

Pathologic diagnosis: Endothelioma.

High-voltage roentgen therapy to the left upper chest was given after the wound had healed; in addition, Coley's toxins (13 injections) were given.

The subsequent course is typical of the disease; after a period of eight months of complete relief, the patient developed pain in the right hip and knee, and later in the skull; diffuse widespread skeletal and pulmonary metastases were noted. The condition was partially relieved by further roentgen therapy, but the course was steadily down-grade.

SUMMARY

Conservative surgical measures are applicable to most benign tumors of bone. While the majority of operable malignant tumors primary in bone require radical surgery, there is a small minority in which less radical methods are justified. The latter include excision, segmental resection, partial resection, total scapulectomy and partial amputation of the hand and foot. The useful limbs that are salvaged by these less radical measures justify the occasional failure which such a policy entails.

Eight illustrative cases are reported.

TRAUMATIC RUPTURE OF THE SPLEEN AND EVENTRATION OF THE SPLEEN

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and

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I N THIS age, properly to evaluate injuries that can happen to a 150 pound body travelling in a conveyance propelled along at the rate of from 50 to 80 miles an hour, one must realize that, the instant there is an impact, the body within the automobile assumes the speed of the vehicle. The 150 pound body has a terrific striking force, therefore it follows that a survivor may have multiple contusions, extensive lacerations, multiple fractures, simple and compound, burns, internal injuries, and may be unconscious. All but one of these, in most instances, may be immediately determined and appropriate treatment started. The one exception—internal injuries—covers wide possibilities and is often the supreme test of diagnostic acumen. This is especially true if the patient be unconscious or narcotized or has sufficient other wounds to account for the state of shock.

Injuries sustained on the lowly wagon are not to be overlooked. Three of our cases occurred on or near this farm necessity. A new cause of rupture of the spleen, hitherto not coming to our attention, is squeezing of the body and lifting off the feet by the arms around the abdomen (case 3).

Practically all authors, in writing of splenic injuries, state that all degrees of force from severest to most trivial, such as coughing or sneezing, may be the etiologic factor of rupture.

In the literature there are a number of case reports of spontaneous rupture of so-called "normal spleen." It is hard to conceive that there was no microscopic lesion of such a spleen: grossly there may not have been, but a surgeon with training in pathology cannot agree with that statement.

Many people who have been in accidents and were not unconscious, not thought to be seriously hurt, collapse and die within an hour or two. Many, if not nearly all, of these deaths were, in our opinion, caused by rapid internal hemorrhage, and some have occurred in hospitals without recognition except at postmortems. We may console ourselves professionally that they would have died

anyway. But would they? The physicians and surgeons, especially
the latter, must meet modern travel accidents with modern medicine.
The larger hospitals keep on night operating crews with instru-
ments sterile, but many of the smaller institutions take at least one
or two hours to get ready for an operation and many of them have
no blood banks or professional donors.

The use of serum or plasma in the treatment of acute hemorrhage
was considered as early as 1918[1] and at the present time is gaining
increasingly wide acceptance. Commenting on the advantages of
serum as an emergency transfusion fluid, Levinson, Neuwelt and
Necheles[2] regarded serum as an effective agent in combating all the
effects of severe hemorrhage and resultant secondary shock except
the loss of red blood cells; they pointed out that serum may be
given in massive amounts without any delay or preliminary testing
as is necessary before administering whole blood. It has been
shown that serum may be prepared, tested and stored in large
quantities over long periods of time without deterioration, without
the need of any antibacterial preservative. Pooling of serums from
many individuals has been shown to suppress the iso-agglutinins
and may therefore be given without any regard for blood groups
and does not require preliminary typing and compatibility. This
permits the aseptic serum to be given without any delay in emer-
gency circumstances.

Citrated blood plasma may also be used in similar manner and
possesses equal advantages. This is obtained by centrifuging ci-
trated blood and decanting the liquid element. Similar to the use
of human serum, blood plasma may be pooled and stored, and it is
always ready for immediate use without preliminary typing and
cross matching. Its use is simple, safe and free from reaction[3]. It
has been shown that with the addition of a preservative it can be
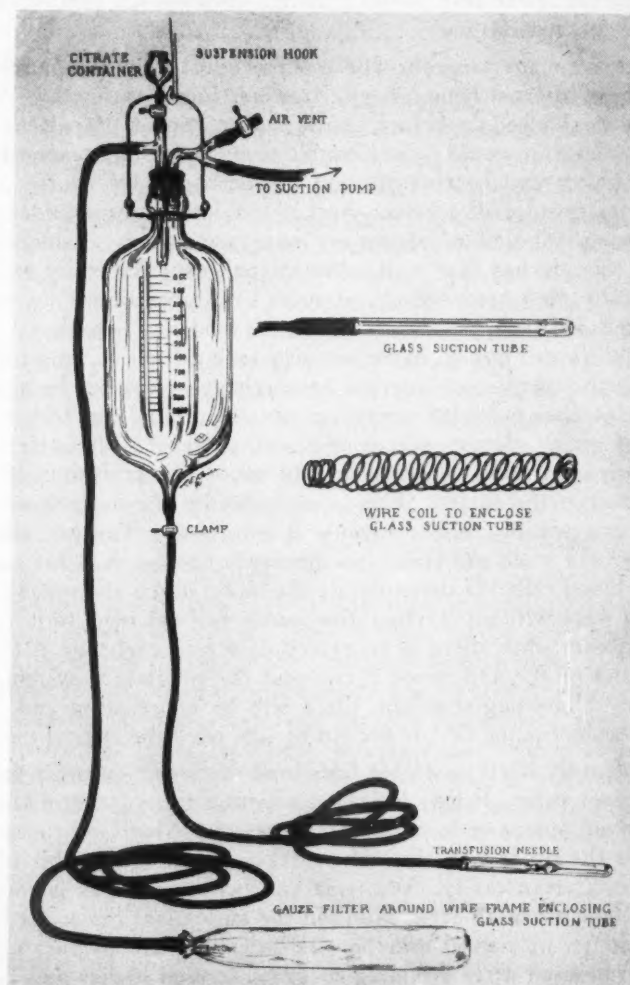kept at room temperature for a number of days, and it is unaffected
by shaking.

In 1934 Flosdorf and Mudd[4] devised a method for the preser-
vation and concentration of serums and other biologic material.
This lyophile process was accomplished by the vacuum dehydration
of material previously frozen in a bath of carbon dioxide ice and
some commercial solvent. By this method serum was converted
into a dry, porous powder and sealed in ampoules, the powder rep-
resenting about one-fourth the original volume of serum. In this
manner, the powdered serum from one individual or pooled serum
from many individuals could be stored and when ready for use
simply redissolved in one-fourth or less its original volume of water
or serum.

In 1938 Aldrich and associates reported the use of this serum either by dissolving it in one-fourth its original volume of distilled water or by using the same amount of compatible blood serum which, in the latter case, made a rather thick syrupy solution suitable for intravenous use.

There are many surgeons who will not operate upon a patient in shock from internal hemorrhage. It seems logical to us that if we stop external bleeding before instituting treatment of patient for extreme shock, it would be reasonable to proceed simultaneously to combat shock and control internal hemorrhage. Of course, it is still better to start all accident-shocked patients on intravenous glucose, acacia solution or serum on mere preliminary examination, for the thought has been well substantiated, experimentally as well as clinically, that hemorrhage produces hyperpotassiemia[6] by withdrawing fluids from the tissues unless the fluid loss is replaced parenterally. It will not do harm but may save a life. If the surgeon is reasonably certain of internal hemorrhage occurring, he should operate at once provided arrangements are carried out to combat shock by giving glucose, serum or blood, preferably the latter. In case glucose is used, the surgeon can count on reinfusion of the free blood in the cavity. This is undoubtedly the best blood the patient can possibly receive because it is his own. The fact that it is a day or a week old makes no difference because it is his serum and his blood cells. If they tolerate the blood in the abdominal cavity for a week without reaction, they surely will not react to it in the blood stream since there is an exceedingly free exchange between lymphatics of the abdominal cavity and the circulatory system. If it is only blood-tinged serum, there will be no reaction and it is really serum volume that is needed to tide over the critical period.

It positively hurts us to see life-blood suctioned out of a cavity and thrown away. It may have come from a clean fracture wound of the liver, spleen or torn mesenteric vessels. May God speed the day that the profession as a whole takes advantage of this blood spilled in a clean cavity. We trust and believe the day is rapidly approaching when all fresh blood in the abdominal cavity, at least of six hours, no matter whether the intestines are perforated or not, can be used after straining of gross foreign bodies and being treated with some sulfonamide preparation. It would be a great boon to humanity and especially to soldiers. In this day and time in small hospitals without emergency blood transfusion equipment or personnel, a surgeon may be justified in using contaminated blood for reinfusion if strained and chemically treated. Bacteriemia occurs more frequently than any of us possibly realize, and now we have the sulfonamide preparations to combat the germ given by re-

infusion. About 22 years ago we began to use with good success
free blood from the abdominal cavity of the severely shocked, rup-
tured ectopic pregnancy cases. Our first operation for ruptured

CITRATE CONTAINER

SUSPENSION HOOK

AIR VENT

TO SUCTION PUMP

GLASS SUCTION TUBE

WIRE COIL TO ENCLOSE
GLASS SUCTION TUBE

CLAMP

TRANSFUSION NEEDLE

GAUZE FILTER AROUND WIRE FRAME ENCLOSING
GLASS SUCTION TUBE

Authors' apparatus for reinfusion of blood found free in the abdominal cavity.

spleen was in 1926: it was followed by uncomplicated recovery. In
those days we used dry new sponges or pads, mopping up the blood,
squeezing into a container covered with new sterile gauze to remove
small clots of blood or bits of tissue. Sodium citrate was already
in the container. The blood was then poured into infusion bottle.

Altogether it was an unscientific and time-consuming procedure but life-saving. We now have installed in our operating room a combined compact suction-infusion apparatus which greatly simplifies the technic and enables us to get practically all the blood cells and serum (see fig. 1).

The spleen is ruptured in 30 per cent of all serious abdominal injuries. The traumatic rupture may be divided into two clinical types: (1) that with immediate hemorrhage, frank rupture of the capsule, and (2) that with delayed hemorrhage, small frank or subcapsular rupture.

In the group showing immediate hemorrhage, the bleeding may be so copious as to cause sudden collapse and death before anything can be done. In less severe cases there are all the signs of internal hemorrhage; pallor, clammy skin, falling blood pressure, rapid, thready pulse, and later drop in red blood cell count and hemoglobin. These signs plus the localizing signs and symptoms to be mentioned later are usually obvious enough in the cases with immediate hemorrhage to justify immediate exploratory operation.

However, it is the second group, that of traumatic rupture with delayed hemorrhage, in which the diagnosis is most difficult and the clinical picture more confusing. It is in this group that lives are lost from delay in operation for lack of diagnosis. It may be well, for this reason, to review briefly the etiology and classic sign and symptoms of rupture of the spleen, as well as some of the pitfalls to a correct diagnosis.

Etiology: Rupture of the spleen may be caused by any form of violence such as blows, kicks, falls and automobile accidents where a heavy, blunt force is applied to the splenic region and transmitted to the spleen through the abdominal and thoracic wall. It may be ruptured by indirect violence. In cases in which the spleen is friable, rupture may be caused by an extremely light blow such as sneezing or vomiting, with no external sign of injury to the skin.

Symptoms: The most consistent symptom is pain, but also the most misleading one. In character the pain may be lancinating or just a dull ache. It may be intermittent due to the stoppage and recurrence of hemorrhage. Its location is usually confined at first to the upper left quadrant but later may become generalized as the blood spreads in the peritoneal cavity. Occasionally, as in two of the cases to be presented, blood may seep into the right paracolic gutter and the pain and tenderness thus caused lead to an incorrect diagnosis of appendicitis. This occurred in the two cases (3 and 6) in which the cause and immediate effect were so trivial that the

patients failed to mention the method of injury which was ascertained only after operation. The pain is frequently referred to the left shoulder (Kehr's sign) due to blood irritating the diaphragmatic peritoneum involving phrenic nerve terminals. However, this is not the only abdominal condition in which shoulder pain occurs. Nausea and vomoting may or may not be present, but are not considered as characteristic or diagnostic.

Signs: There may be no sign of external injury to the skin: therefore it is always important to try to get history of any injury to the splenic region.

Tenderness and rigidity are always present. They may be marked or slight, and are usually localized in the left upper quadrant. It must be remembered that occasionally it is more intense in the right lower quadrant, or may be generalized, depending on the distribution of the blood in the abdomen.

There may or may not be dulness in the left with resonance in the right flank (Ballance's sign). This sign is difficult to elicit and depends on the quantity of the hemorrhage. Usually damage is done trying to elicit it, and it may start fresh and fatal hemorrhage.

Rectal tenderness has been stressed by some, this tenderness being caused by blood in the culdesac. Here again this is not a constant sign and depends on considerable hemorrhage.

Lowered blood pressure, accelerated pulse, pallor and shock come with sufficient hemorrhage, but at the time of first examination these may be normal. The blood pressure, pulse rate, blood counts and hemoglobin content are of tremendous importance in watching and re-examining the patient, and should be closely studied. Hemoconcentration ascertainable by falling drop method can be of inestimable value in determining the degree of shock and blood loss.

Diagnosis: It becomes obvious from this brief review of the signs and symptoms that the diagnosis of ruptured spleen may be simple or very difficult. It also becomes obvious that the diagnosis must in the last analysis depend on suspicion, close observation and keen judgment on the part of the examiner in his interpretation of signs and symptoms. Paracentesis abdominis for presence of blood can be of great value in the probable diagnosis.

The main difficulties which arise may be summarized briefly:

1. Administration of morphine or other narcotic before diagnosis is established.

2. Absence of evidence of injury to the superficial tissues.

3. Failure to obtain any history of trauma which would likely injure the spleen.

4. Concealment by multiple injuries.

5. Characteristic recession in symptoms in recurrent hemorrhage.

The patient when first examined may have recovered from the initial shock and present a normal pressure and pulse, with only vague upper abdominal pain. It is only by close observation of these patients, for as long as two weeks, that death from delayed hemorrhage can be prevented. It is to be remembered in this connection that rupture of the spleen seldom if ever heals. In one large hospital a review of 25,000 autopsies failed to reveal any evidence of healed rupture of the spleen.

The following are brief case summaries of ten cases occurring at Park View Hospital between Dec. 10, 1926 and Oct. 25, 1940, nine occurring since April 2, 1938. All of these patients were operated upon by Dr. E. S. Boice, Dr. N. P. Battle, or the senior author, and there were two deaths.

REPORT OF CASES

CASE 1.—G. P., a white schoolboy, had been hit by an automobile about 10 minutes before admission to hospital on Dec. 10, 1926. He had been knocked unconscious so he did not know what part of the body the car hit. He complained of pain in the left shoulder and more severe pain in the upper abdomen. Examination of the abdomen revealed acute abdominal distress and moderate shock. Blood pressure was 70/50; pulse 120. Examination of chest and heart was negative. There were slight abrasions of skin of hands. The reflexes were normal. The abdomen was acutely tender in the left upper quadrant, with slight rigidity, no masses.

Laboratory reports: White blood count 24,400; polymorphonuclears, 86; hemoglobin 75; urine negative. No x-ray was made.

Clinical impression: Rupture of spleen.

Operation: The patient was operated upon immediately. A large amount of free blood was found in the abdominal cavity. A large gap was found on the posterior surface, extending almost through, a normal size spleen. Four hundred cubic centimeters of the abdominal blood was infused back into the patient by the usual method. The spleen was removed.

Postoperative Course: Convalescence was uneventful, the patient being discharged as well 21 days after admission.

CASE 2.—On Aug. 12, 1935, a 28 year old farmer was riding on an unlighted wagon which was hit by an automobile. Knocked unconscious, he was brought to the hospital immediately. On admission the patient was delirious, with short intervals of apparent lucidity. He complained of pain all over the abdomen, especially in the left quadrant, and of pain in the right leg. No complaint was made about his injured head. The history was difficult to obtain.

Examination: Examination revealed two small but deep lacerations on left lower portion of the occiput. The pupils were normal in size and in reaction. Chest and heart were normal. Bloodpressure was 90/58; pulse, 100. There was marked abdominal tenderness in the left upper quadrant with slight rigidity. There were also minor contusions and lacerations of the right leg and ankle. Reflexes were normal.

Laboratory reports: White blood count 19,500; polymorphonuclears 88; red blood count 3,600,000; hemoglobin 70; urine showed blood 4 plus and pus 6 cells per low power field.

Diagnosis: Ruptured spleen, concussion of brain, probable fracture at base of skull and subcapsular rupture of kidney.

Preoperative preparation: 500 c.c. acacia solution intravenously.

Operative findings 4 hours after admission: The peritoneal cavity contained approximately 2 quarts of blood which had escaped as a result of a ruptured spleen. One of the ruptures extended from about the middle of the free border, transversely through the pedicle, completely dividing the spleen. One half of the spleen was further broken into two parts of about equal size. The right kidney was not examined, but there was no rupture of the left kidney, of hollow viscus or of liver. The free blood was sponged up, citrated, strained and 1,400 c.c. infused intravenously.

Several hours after operation a hemopneumothorax was discovered. The origin of blood in the chest was never definitely established. (Later, the embalmer reported that he recovered about a half gallon of blood from the left chest.) The patient never regained consciousness. No definite paralysis was ever made out. Lumbar puncture was made and showed only 10 cells; 23 c c. of spinal fluid was removed. He was given glucose intravenously and liver extract. His blood urea continued to mount as shown in three examinations, being 228 mg. per 100 c.c. before death on the third postoperative day. It was thought that kidney deficiency and undetermined lung injury were largely responsible for his death.

Partial autopsy of abdomen: The peritoneal cavity was clean, with no evidence of further bleeding, peritonitis or other damage of hollow viscera. The liver, urinary bladder and splenic pedicle were normal. The left kidney capsule was unruptured but had several subcapsular tears, one extending into the kidney pelvis. The right kidney was not ruptured. The diaphragm was not ruptured or punctured.

CASE 3.—A salesman, aged 22, was admitted at 10 p. m., April 2, 1935, complaining of generalized abdominal pain, especially in the right lower quadrant and left shoulder. Four to five hours previously he had been seized with generalized abdominal pain which had progressively become more severe. There was a definite pain or deep-seated ache in the head of left humerus (Kehr's sign). He became nauseated but did not vomit. Soda water by mouth and an enema made him worse. He noticed that the pain was made worse by flexing the legs on thigh and thighs on abdomen. He had experienced no similar condition.

Examination on admission revealed the chest and heart were negative. Blood pressure was 126/76; pulse 100. The abdomen was extremely tender, rigidity

more marked in the right lower quadrant. There were no masses nor evidence of free fluid. Other examinations were negative.

Laboratory findings: White blood count 18,200; polymorphonuclears 90 per cent; hemoglobin 80 per cent; urine, trace of albumen, 8 pus cells per low power field.

Clinical impression: Gangrenous acute appendicitis.

Operative findings: McBurney incision was made. On opening the peritoneum blood flowed out. We realized immediately that we were most likely dealing with a ruptured spleen as patient was a man with pain in left shoulder and hemorrhage. The McBurney incision was closed and a high left rectus opening made. The pedicle of the spleen was clamped, blood soaked up with fresh sponges and transferred from a receptacle to an intravenous bottle. About 1,000 to 1,500 c.c. of abdominal cavity blood was reinfused. Splenectomy was performed without draining. The patient recovered from operation uneventfully except for some secondary hemorrhage from wound, and some elevation of temperature. He was discharged as well in four weeks.

This patient was questioned further after operation and it was found that on the day before admission to hospital he had been scuffling with a friend who picked him up by placing arms around his waist from behind and attempted to put him out of a door. He resisted with feet against door facing. However, at no time during this struggle did he have any pain, but he had noticed a peculiar feeling after eating a full dinner the next day, and about four hours later he began to feel weak and had pain in the abdomen.

Comment: This patient most probably sustained a subcapsular rupture of the spleen and, the following afternoon, capsular rupture.

CASE 4. On Nov. 9, 1935, a farmer aged 18, fell off back part of wagon, the tailgate striking him across the upper abdomen. He immediately experienced considerable pain in left side and in shoulder, but he remained conscious and started back to work. Shortly afterward however, the pain became more severe and he became weak, so he went home to bed. The next day he gradually became weaker and the pain no better. Approximately 36 hours after the accident, he was admitted to the hospital.

On admission the patient appeared in semi-shock and complained of severe abdominal pain and pain in the left shoulder. Respiration was short and fast, and the skin moist. Blood pressure was 150/100; pulse 140; the color somewhat pale. Examination of heart and chest was negative. The abdomen was rigid and markedly tender in the left hypochondriac region. There were no masses and no obtainable signs of free fluid. Urine was negative. Blood counts were not reported. Blood smear was positive for tertian malaria.

Clinical impression: Rupture of spleen or hollow viscus.

Operative findings one hour after admission: There was a moderate amount of free blood in the peritoneal cavity. The patient had not bled much which accounted for the absence of signs of hemorrhage. The large spleen was ruptured along the inferior border and torn almost completely into two parts in the transverse plane. Splenectomy was performed through a high left rectus incision. The spleen weighed 400 Gm. During the operation 500 c.c. acacia and 400 c.c. normal salt solution were given intravenously.

Postoperative course: Convalescence was complicated by atelectasis of right middle lobe of lung and by active tertian malaria. Blood transfusion was given on day of the operation. The patient made an otherwise uneventful recovery, the wound having healed nicely on discharge three weeks after admission.

CASE 5.—Forty-two hours previous to admission to hospital on April 1, 1936, a 6 year old girl fell off a plank about 4 feet from the ground. She thought she had fallen on a brick. She walked to the house but was complaining of a little pain in the abdomen. She vomited several times that evening, and later pains in the abdomen became more severe. About midnight she was seen by a doctor who found considerable gas. She had not eaten since the accident but had drunk a good deal of water. The following day she vomited frequently and continued to complain of pain.

Admission examination: The next morning the child seemed to be resting comfortably; heart and lungs were normal. The abdomen was distended with slight, generalized rigidity and tenderness, the tenderness being more marked in the left upper quadrant.

Laboratory reports: The pulse was 136; temperature 100.5; white blood count 22,400; polymorphonuclears 87 per cent; hemoglobin 65 per cent; red blood count 4,320,000; urine negative.

Fluoroscopic report: The left lung was slightly hazy and the left diaphragm slightly raised, with mild fixation; there was no air between lung and diaphragm.

Clinical impression: Possible rupture of hollow viscus or spleen; possible retroperitoneal hemorrhage.

Operative findings: The abdomen was opened through high left rectus incision. The abdomen contained approximately 150 c.c. of discolored bloody fluid and a few small clots. On exposure of the spleen, a tear was found extending from the medial border at the junction of the upper and middle thirds obliquely downward to the outer border. The tear extended from a distance of one half to one third of the thickness of the spleen. There was no hemorrhage or rupture or other damage to any of the remaining abdominal viscera. The tear in the spleen was closed with three figure of 8, and two plain, catgut sutures. Bleeding was satisfactorily checked. The patient began to grow worse and abdomen was closed rapidly, with drainage. During operation the patient received by hypodermoclysis 175 c.c. saline solution. Transfusion of 300 c.c. of blood was made at completion.

Postoperative course: The child received a blood transfusion the day after operation. Convalescence was uneventful and patient was discharged 16 days after admission.

CASE 6.—Thirty-one hours before admission to hospital on Nov. 30, 1936, a farmer of 38 was taken with generalized abdominal cramps, vomiting and diarrhea. This lasted all night, and next morning he took magnesium sulphate. The pain continued, with no results from medicine, so he took more, but vomited it. The pain never localized. The patient developed a catching pain in the right shoulder when turning in certain positions or taking deep breaths. He had not had any previous attacks like this, or any chills.

Examination on admission: The patient was in much distress, complaining of severe abdominal pain. The heart and lungs were normal. The blood pressure was 130/70; respirations 32; pulse 108; temperature 98.6. The abdomen was moderately distended. There was rather marked generalized tenderness and pain on percussion; no definite localization. No definite rigidity was present.

Laboratory reports: White blood count 9,200; polymorphonuclears, 83 per cent; urine, albumin faint trace. Blood smear positive for malaria.

Because of lack of definite localization, it was thought best to watch him for a while. He was given hypodermoclysis and later 1,000 c.c. of glucose intravenously. Later during the day, the patient developed fairly well localized tenderness in right lower quadrant, and it was decided that he had acute appendicitis with some peritonitis.

Operative findings: The abdomen was opened in the appendix region and free blood found. A high left rectus incision was immediately made in order to explore the spleen. It was very large, weighing a pound and one-half, and was bleeding from the pedicle. The abdominal cavity was filled with blood, 600 c.c. of which was saved, citrated, and reinfused after he had received 500 c.c. of acacia.

Splenectomy was done with difficulty because of the size of the spleen and its short pedicle and operative field very greatly obscured by blood.

Postoperative course: Convalescence was uneventful except for elevation of temperature from malaria which was difficult to get under control. Plasmochium and quinine were used.

Pathologic report: Chronic splenitis.

After operation the patient said he had been hit in the left side (splenic region) with a bean pole on the day of onset of the pain, and had forgotten to mention it.

CASE 7.—A merchant, aged 19, was admitted as an emergency case at 1 p. m., Dec. 19, 1936 following injury in a car wreck, complaining of pain in the abdomen, chest and left shoulder.

Examination on admission: Blood pressure was 120/80; pulse 125; respirations 50. He assumed a position of flexion of thigh on abdomen. Blood pressure at 2:30 p. m. had dropped to 98/60 and at 3 to 84/68. Blood counts showed rapid rise of leukocytosis with shift to left. The abdomen was moderately rigid and tender, especially in upper left quadrant. He had minor lacerations and a right Colles' fracture. Exploration seemed indicated.

Clinical impression: Rupture of intra-abdominal organ, possibly spleen.

Preoperative Preparation: 1,100 c.c. of glucose intravenously and 300 c.c. were administered.

Operative Findings: Abdominal cavity contained a large quantity of blood. On the anterior surface, on a line with the pedicle, the spleen had a large tear which extended almost the entire thickness of the organ. No other intra-abdominal injury was found. Splenectomy was done. The pedicle was clamped in sections, examined and ligated. One ligature slipped at upper pole, causing considerable hemorrhage. Several hundred cubic centimeters of blood were

recovered from the cavity, citrated and infused. The abdomen was closed with drainage.

Postoperative Treatment: 550 c.c. of blood transfusion and 1,000 c.c. of 7 per cent glucose, etc.

Postoperative Course: Patient's condition grew progressively worse following operation. The next day he began expectorating bloody mucus. Temperature rose to 102; pulse 145. It is probable that this patient had pneumonia, but no conclusive evidence was found in chart. He died on the third day after operation.

CASE 8.—A 19 year old boy 12 hours before admission was in automobile wreck and had been knocked unconscious for an unknown period. His physician gave him morphine and sent him home. There he had a sensation like the desire to defecate, but he had been unable to do so. Pain in the epigastrium was followed by nausea and he vomited once. He was cold; on getting warm he broke out in cold sweat. He received three hypodermics within four hours after accident. There was no further vomiting, no bowel movement but continued epigastric pain.

Physical examination was negative except for small depression in the left temporal region. There was no tenderness. Blood pressure was 72/40, pulse 28, temperature 99.2 F. Abdomen was flat, with some gas, no fluid; generalized tenderness and rebound. Rigidity was probably obscured then by morphine.

Impression: (1) Intra-abdominal injury with hemorrhage and (2) skull fracture.

Laboratory examination: Urine negative. Blood: White blood count 29,800, polymorphonuclears 90 per cent, of which 14 were stabs, lymphocytes 10; red blood count 4,040,000; hemoglobin 62 per cent. Blood Wassermann negative. Serum protein 6.29 mg.

X-ray films showed elevation, fixation left hemidiaphragm, associated with soft fuzziness of its superior aspect.

Immediately after admission the patient was given 1,000 c.c. of 8 per cent glucose. Blood pressure rose to 105/70.

Preoperative diagnosis: First, rupture of liver of spleen; second, laceration of mesentery.

Operation was started at 4:40, ending 6:10. Pulse was 136. He received during the early part of the operation 1,000 c.c. blood intravenously. An additional 500 c.c. of his own blood was reinfused at 5.

Findings: Large amount of free and clotted blood, estimated at about two quarts, was revealed. A large piece of spleen, 2½ inches of lower pole, was readily found since it was fixed to the pancreas and transverse colon. The central portion of the spleen was a mass of pulp. The upper pole was behind the stomach and attached to it by the brevia gastrica vessels. Blood was welling up from the macerated stump. After considerable effort the pedicle was gotten together so that a large clamp could be applied around the mass, lightly at first, and, after controlling bleeding and under vision, the clamp was tight-

ened and a double ligature of No. 3, 20 day, catgut tied. It was then seen that the parietal peritoneum was lacerated for about 2 inches about opposite to where the central portion of spleen would have been. There was no external evidence of a wound on the opposite skin surface. Much of the body of the spleen was removed in mushy pieces and small isolated masses.

Postoperative Diagnosis: "Exploded" spleen.

The patient recovered and was discharged Oct. 14, 1940, 42 days after admission. He had developed a low-grade infection from the stab wound, drainage made to the left of the left rectus incision, necessitating such a long stay.

Comment: This boy was undoubtedly still in shock 12 hours after injury, and we believe that the short preoperative preparation, intravenous glucose and heat, thus affording time to type donors, together with 1,500 c.c. of blood, were life-saving. The bleeding was sufficiently slow for him to re-absorb from the abdomen much of his blood serum before operation. In hemorrhages one must consider the concentration of blood in the preoperative findings. Otherwise, the red blood count never would have been 4,040,000 and hemoglobin 62 per cent. Also to be considered is the necessity for transfusion with whole blood or blood serum and the free use of intravenous glucose.

CASE 9.—A child of 6 had sustained an injury to the back and abdomen 22 hours earlier while riding on an unloaded small wagon. He had fallen between the wheels, the rear wheel passing over the lower back. He had been unable to walk after injury. He suffered mild local pain and during the night was nauseated, vomiting 2 or 3 times. He had voided 4 times since injury. The urine was described as slightly reddened. He had one brown movement of the bowels. He had taken nothing by mouth but small amounts of water. Fever was present for first time on day of admission. He had been under constant care of his local physician.

General physical examination was negative except mild tenderness over lower lumbar vertebrae. The skin felt normal; the color was ruddy. Blood pressure was 120/68, pulse 128, character good. There was moderate distention and generalized tenderness over abdomen. The walls were flaccid, no rigidity or masses being felt. Superficial abrasions were in the malar and in fourth lumbar regions.

Impression: Questionable perforation of hollow viscus.

Laboratory reports: X-ray films were negative for air in the peritoneal cavity. Urine showed sugar 4 plus, but the child patient had had glucose intravenously. White blood count 21,700, polymorphonuclears were 80 per cent, 20 of which were stabs, lymphocytes 20; red blood count 4,290,000, hemoglobin 61 per cent. Type IV. Patient was taken to operating room at 10:38 P. M., about six hours after admission.

Preoperative diagnosis was intra-abdominal injury, "ruptured viscus."

Postoperative diagnosis: Ruptured spleen.

Findings: There was a large amount of blood in the peritoneal cavity. The spleen was first thought not to have been injured but there being no injury to liver or intestines, the spleen was re-examined and a rupture of the hilum found. The posterior portion of the capsule was all that was holding the two halves together. A right paramedian incision was made with transverse extending to the left. The pedicle was clamped and ligated with No. 2, 20 day, catgut. During operation his condition became critical. He received 500 c.c. 19 per cent glucose intravenously.

Three hours after operation the pulse went to 165, respirations 65 and rectal temperature 104.5. At this time atelectasis of the lower lobe of the right lung was discovered. He was bronchoscoped by Dr. C. W. Bailey, who reported the trachea and bronchi of lower right left lobes practically filled with mucus and vomitus. Considerable material was removed. He received 500 c.c. citrated blood and later in the day frank pneumonia developed. Sulfathiazole was given. On fifth day the temperature was normal. Convalescence was satisfactory.

CASE 10.—While riding his bicycle on Sept. 12, 1936, a 13 year old boy was struck by an automobile; it is thought the door handle point entered the abdominal wall near the midline on the level of the eleventh rib and tore the wall transversely to the left, exposing the eleventh and twelfth ribs back to the erector spinus muscle border, eventrating a greater portion of the stomach, entire spleen and part of the transverse colon. There was a small tear in the margin of the spleen which was bleeding moderately. He was brought immediately to the hospital, and carried to the operating room. Blood pressure was 130/70. He was given 80 c.c. anaerobic and 1,500 units tetanus antitoxins.

Operative findings: These were as stated above with additional findings of rupture of the diaphragm 8 cm. in length. The stomach and colon had not been damaged. There was a bruised area in the spleen measuring 4.0 by 1.5 cm. in addition to the slight tear. The left lung was collapsed and the pericardium could be seen through the diaphragmatic opening.

Operation: The exposed viscera were washed with 2 gallons of warm saline solution tinged with aqueous merthiolate after the surrounding skin had been cleansed. The eleventh and twelfth ribs were resected for a distance of 3 or 4 cm. The diaphragmatic opening was closed. The spleen was removed and the pedicle ligated.

Patient left operating room with pulse 150, respirations 40 and temperature 99 F. The day after operation patient received a transfusion of 300 c.c. of blood. He had a satisfactory convalescence and was discharged on the fifteenth day.

TREATMENT

Without treatment the mortality, according to the literature reviewed, is about 97 per cent. With treatment it is around 30 to 50 per cent. Hemorrhage is the usual cause of death. Among 168 fatal cases collected by Berger[7] 145 died the first day. In 90 per cent the death was due to hemorrhage, and in the remainder to sepsis. Since hemorrhage seems to be the predominant factor in the

Some Symptoms and Clinical Findings

No.	Abdominal Pain	Shoulder Pain	B.P.	Pulse	WBC	Polys	Hb.	RBC	Blood Urea	Malaria	Spleen
1	Yes	Yes	70/50	120	24,400	86	75				
2	(?*)	(?*)	90/58	100	19,500	88	70	3.6	228		
3	Yes	Yes	126/76	100	18,200	90	80				
4	Yes	Yes	150/100	140	Not recorded					Yes	410 Gm.
5	Yes	(1)		136	22,400	87	65	4.3			
6	Yes	(1)	130/70	108	9,200	83				Yes	Large
7	Yes	Yes	120/80x	125	24,900	75	90	4.4			
8	Yes	(1)	72/40	128	29,800	90	61	4.0			
9	Yes	(1)	120/68	128	21,700	80	61	4.2			
10	Eventrated Spleen										

(*) Unconscious.
(x) 30 minutes later BP 78/60; next 30 minutes BP 84/68.
(1) No record of inquiry being made.

mortality, the treatment is obviously the quickest way of controlling hemorrhage and restoring blood loss. There are three accepted surgical procedures—suture, tamponade and splenectomy. The method of choice is splenectomy. It was used in every case cited except one, in which suture was used.

Another important procedure in treatment is the reinfusion of citrated blood, taken from the patient's abdomen at the time of operation. In all of the cases mentioned, where there was a good deal of free blood in the abdomen, this was done. There was no reaction from this even in one case where the blood was reinfused after straining through gauze only. For fear of producing reaction, resterilized gauze should never be used either in mopping or straining blood.

Following the operation, these patients should be watched closely for secondary hemorrhage as well as for signs of sepsis and pneumonia. It is to be remembered that most of these patients have lost considerable blood and have low resistance to infection. Lastly, we would call particular attention to the fact that a patient who has just recovered from shock can be easily reshocked by very little blood loss or trauma. Patients who are under morphine seem to us especially susceptible of shock. It seems to carry them to a point of complete exhaustion before the sudden collapse, and many such deaths are blamed on anesthetics.

In summary, the following important points should be remembered:

1. Rupture of the spleen is not a rare but a common occurrence in the traumatized abdomen.

2. The trauma does not have to be severe to cause rupture, and the signs of rupture may be long delayed following the trauma.

3. This condition, when not diagnosed and operated on in time, is always fatal and the only safe plan is close observation and immediate operation even on presumptive evidence. None of the signs or symptoms is infallible, but a clear understanding of their pathogenesis is essential.

4. Splenectomy is the treatment of choice.

5. The reinfusion of citrated blood from the abdominal cavity at time of operation is a safe, beneficial and often life-saving procedure.

6. If in doubt, explore by incision or aspiration.

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SULFA-DRUGS AND INTERNAL FIXATION IN THE TREATMENT OF COMPOUND FRACTURES.

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O NE year ago a preliminary report was made on the preventive or prophylactic action of sulfanilamide on infection in compound fractures. The beneficial action of sulfanilamide as a bacteriostatic agent was evaluated with extreme conservatism; first, because the series of cases was small, and second, because a number of so-called cures had been advocated previously and eventually were proved to be of little or no value. Since this report, a larger series has been accumulated in which sulfanilamide and other chemotherapeutic agents (neoprontosil, sulfapyridine, sulfathiazole) have been utilized.

As this series has grown in size, a greater proportion of the cases have had internal fixation in the face of potential or active infection; a procedure which formerly would have been contrary to all generally accepted surgical principles. It is the purpose of this survey to show the beneficial effects of the sulfa-drugs on the healing of compound fractures with or without some form of internal fixation.

The 90 patients in this series who received sulfa-drugs as a prophylactic measure were divided into four groups; (1) fresh compound fractures, or those seen within 24 hours after the initial injury; (2) compound fractures of 24 hours' to three weeks' duration; (3) compound fractures with an active draining infection of more than three weeks' duration; (4) old infected compound fractures with a latent or potential infection. The sulfa-drugs were administered to these 90 patients in various combinations. Thirty-one of the 90 received sulfanilamide in the wound, followed in 24 hours by 1 Gm. of sulfanilamide or sulfathiazole by mouth every four hours. If no sulfanilamide was placed in the wound, the initial dosage of the sulfa-drug was 3 Gm. followed by 1 Gm. every four hours. Blood concentrations were, as a rule, made on the second or third day, and the dosage decreased or increased in an endeavor to approach an average of from 5 to 6 mg. per cent concentration. The earlier patients in this series received sulfanilamide and neoprontosil and, rarely, sulfapyridine; the latter two have been discontinued.

The present practice is to place sulfanilamide in the wound, followed in 24 hours by 1 Gm. of sulfathiazole by mouth every four hours. This seems to be a satisfactory combination, although the series is relatively small. The reasons for this combination can best be expressed by the bacteriology of the infection: Gas 3, mixed (streptococcus and a gram negative bacillus) 1, staphylococcus 12, bacillus chauvaéi 1, and unrecorded 4. These figures represent the total
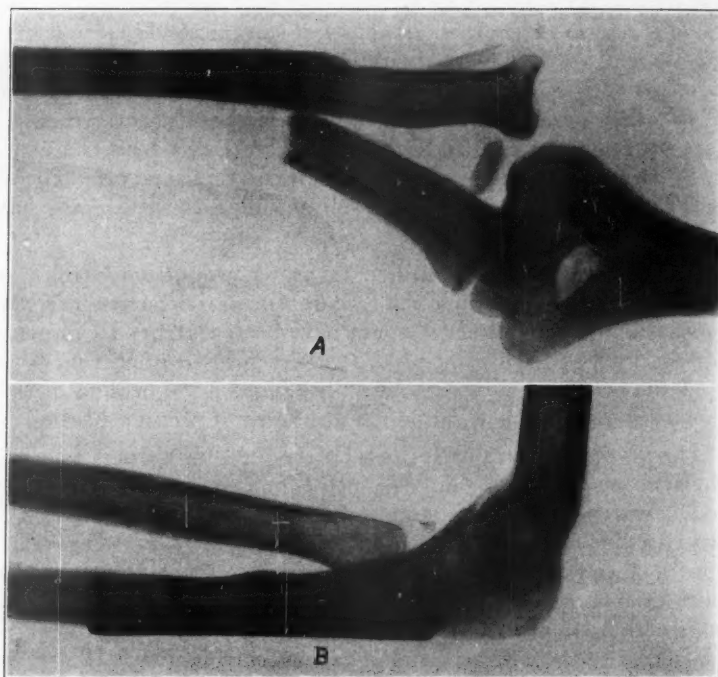

Fig. 1.—A. Monteggia fracture (fracture of ulna with dislocation of head of the radius); compound fracture of the ulna of moderate degree.
B. Seven months later; wounds healed without infection.

number of infections or exacerbations of infections in the series of 90 patients. The general impression has been that sulfanilamide and neoprontosil have a less favorable prophylactic action upon staphylococcic than upon streptoccic infections; in the small series of patients to whom sulfathiazole has been administered, the response in staphylococcic infections, not only in this series but in other staphylococcic infections of bone as well, has been more favorable. Sulfathiazole as yet has not been placed in any wounds, but is given by mouth.

Twenty-two patients of this series received more than 40 Gm. of sulfa-drugs. The largest doses for the individual drugs were as follows: sulfanilamide, 122 Gm.; neoprontosil, 100 Gm.; sulfa-thiazole, 51 Gm. One patient, who had received 39 Gm. of sulfa-
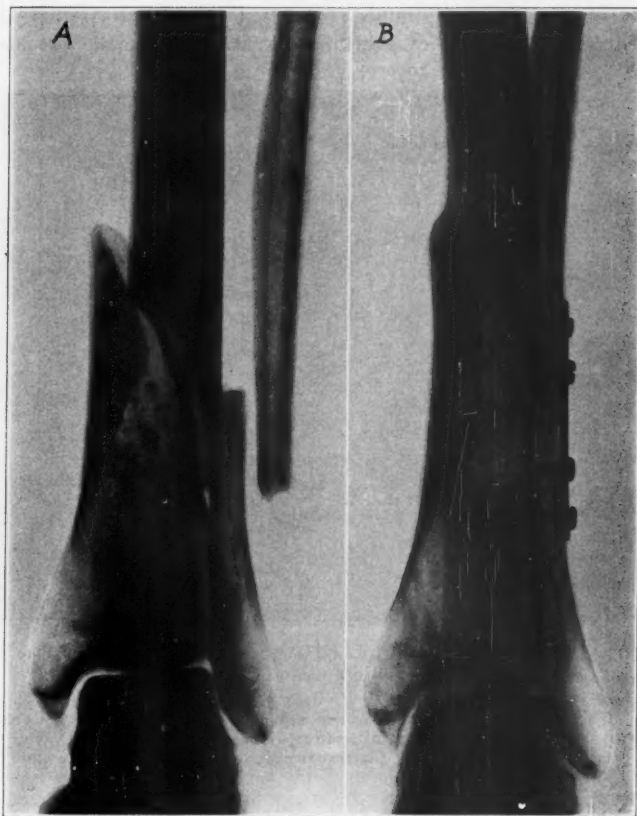

Fig. 2.—A. Severe compound fracture of the tibia and fracture of the fibula, sustained by an explosion of a stove. Fibula was plated through separate clean incision. After proper debridement, sulfanilamide crystals were placed in the wound over the tibia and the skin closed. Primary healing ensued.

B. Seven months later. The fibula and tibia were solidly united in excellent position. No infection.

nilamide, developed bilateral stag-horn renal calculi; the compound fracture did not become infected. Whether or not the sulfanilamide contributed to the renal calculi was not ascertained. Four months after the initial injury, the patient succumbed to a pyonephrosis of three months' duration, with a terminal staphylococcic septicemia.

Prior to the introduction of vitallium, internal fixation by ordinary ferrous metal plates had been attended by so many undesirable and even disastrous complications that the method fell into rapid disrepute. The success of vitallium for internal fixation in selected simple fractures, however, led to the use of the metal in conjunction with sulfa-drugs in compound fractures. Some form of metallic internal fixation, i.e., either vitallium or stainless steel, was applied

Fig. 3.—A. Severe compound fracture of the tibia and fibula. The wound involved the knee joint with a 6 inch exposure of the tibia.

B. Open reduction with fixation by a vitallium pin and one stainless steel wire loop. The wound drained for several months, eventually necessitating a sequestrectomy and removal of the metal fixation. Healing three weeks following this procedure of the soft tissue; the fracture site was solid eight weeks later.

to 54 bones in 53 patients, as follows: vitallium plates, 25; vitallium screws, 13; stainless steel wire loops, 5; stainless steel nails or pins, 10; autogenous bone pegs, 1. The metal fixation in potentially infected wounds, or even in the face of active infection, was well tolerated.

FRESH COMPOUND FRACTURES

Fifty fresh compound fractures have now been treated by the following methods: Thorough mechanical levage by saline irrigations; debridement; insertion of metallic internal fixation when indicated, and primary closure of the wound. In 21 of these 50, prior to closure sulfanilamide was placed in the wound in varying quan-

tities of from 5 to 20 Gm. In order to evaluate the results of sulfanilamide therapy, a comparative analysis has been made between this group and a larger number of compound fractures in which neither internal fixation nor the sulfa-drugs were used. The results of this study are summarized in table 1. There was approximately the same percentage of union and non-union.

TABLE 1

Results of Treatment in One Hundred Twenty-Five Cases of
Fresh Compound Fractures (Under Twenty-Four Hours)

RESULTS	Sulfanilamide Therapy			No Sulfanilamide Therapy		
	No.	Per Cent	Avg. Time Union (Months)	No.	Per Cent	Avg. Time Union (Months)
Not Infected	38	76%		50	66.6%	
Union	31	62%		43	57%	
Non-union	6	12%	2.4	5	7%	2 6
Incomplete	1	2%		2	3%	
Infected	12	24%		25	33.3%	
Union	7	14%		13	17%	
Non-union	3	6%		4	5%	
Osteomyelitis	(4)		4	(8)		5.4
Amputation	1*	2%		3*	4%	
Died	1**	2%		3***	4%	
Incomplete	0			2	3%	
	50	50		75	75	

*For gas gangrene; lived.
**Gas gangrene following gunshot wound of ilium and abdomen.
***Two patients died of gas gangrene; one from streptococcic septicemia.

Osteomyelitis as a sequela of compound fracture was decreased slightly in incidence, and to a marked degree in virulence and morbidity. Primary closure of wounds in conjunction with sulfa-drug therapy certainly did not increase the incidence of gas gangrene; two cases occurred in this series, both shotgun wounds of fleshy parts, in contrast to five cases of gas gangrene in the control series.

The average time required for union in the two groups was approximately the same. Other favorable conclusions were as follows: The incidence of infection was lowered 10 per cent. Only one in the series that received sulfa-drugs died as a direct result of an infection (gas gangrene); in the control group, three patients died as a result of infection (two died of gas gangrene, one from streptococcic septicemia).

In considering the relation of internal fixation to infection and union, 10 mild compound fractures have been eliminated in this

TABLE 2

*Results of Treatment with Sulfa-Drugs in Mild, Moderate, and Severe
Fresh Compound Fractures*

RESULTS	Mild Fractures		Moderate Fractures		Severe Fractures	
	Internal Fixation	No Int. Fixation	Internal Fixation	No Int. Fixation	Internal Fixation	No Int. Fixation
Not Infected 0		9	8	7	6	8
Union	0	9	6	7	3	6
Non-union	0	0	2	0	2	2
Incomplete	0	0	0	0	1	0
Infected 1		0	2	0	5	4
Union	1	0	0	0	4	2
Non-union	0	0	2	0	1	0
Amputation	0	0	0	0	0	1*
Gas gangrene	0	0	0	0	0	1*
Osteomyelitis	(1)	0	0	0	(3)	0
Totals	1 1	9 9	10 10	7 7	11 11	12 12

*Gas gangrene—one died; the other lived following amputation.

TABLE 3

*Results of Treatment with Sulfa-Drugs in Compound Fractures of 24 Hours'
to 3 Weeks' Duration*

Results	Internal Fixation	No Internal Fixation
Not infected—4		
Union	2	1
Non-union	1	0
Infected—5		
Union	0	1
Non-union	2	0
Amputation	2*	0
Osteomyelitis	0	0

*(1) Gas gangrene 8th day after injury, 5th day postoperative; (2) amputation for diffuse infection of leg by B. Chauvaéi (black leg).

group, as there is a reasonable expectancy of a high percentage of union and healing. Of the remaining 40, 21 had internal fixation. Of this group, 13 had union, 7 non-union and 1 incomplete; 14 healed and 7 became infected. Of the 19 that had no internal fixation, 15 had union, 2 non-union, 1 died and 1 had an amputation: 15 healed and 4 became infected. From these figures one would assume that, despite the sulfa-drugs and their favorable influence on the series as a whole, as regards infection, internal fixation had

TABLE 4

Results of Treatment with Sulfanilamide of Thirteen Cases of Compound Fractures with Chronic Infections

Results	Internal Fixation—No Postoperative Exacerbation of Infection		No Internal Fixation—No Postoperative Exacerbation of Infection	
Union	9	average time of union—5.3 mos.	2	average time of union—4.5 mos.
Non-union	2		0	
	11*		2	

*Two bones were plated in one patient, making 12 instances of internal fixation with no exacerbation of infection.

TABLE 5

Results of Treatment with Sulfa-Drugs of Old Compound Fractures with Latent or Potential Infections

Infected—4 (all staphylococcus)	Not infected—14
Internal fixation—2	Internal fixation—11
No internal fixation—2	No internal fixation—3
Drainage following initial injury	Drainage following initial injury
Average—7.7 months	Average—5.4 months
Wound healed prior to operation	Wound healed prior to operation
Average—5.1 years	Average—13.2 months

Type of Operation

Open reduction and plating—3	Osteotomy and plating—1
Transplantation of fibula to replace	Dual bone graft—3
defect of tibia (2 stage)	Arthroplasty—4
	Osteotomy—1

Bone grafts—5

an unfavorable influence upon the healing of the fracture and favored infection.

On the contrary, the percentage of union in the series as a whole was essentially the same as the control series. Internal fixation cannot be considered as a major contributing factor to non-union as many of the severe fractures in which internal fixation was used would, according to previous averages, have eventuated in a high percentage of non-union. The contrast between the fractures with and without fixation is exaggerated by the fact that the latter group contained a large number of fractures that would have eventuated in union (Potts', supracondylar of the humerus) even in the presence of infection. The more severe the fracture of a long bone, the more reason for employing internal fixation, thereby expediting
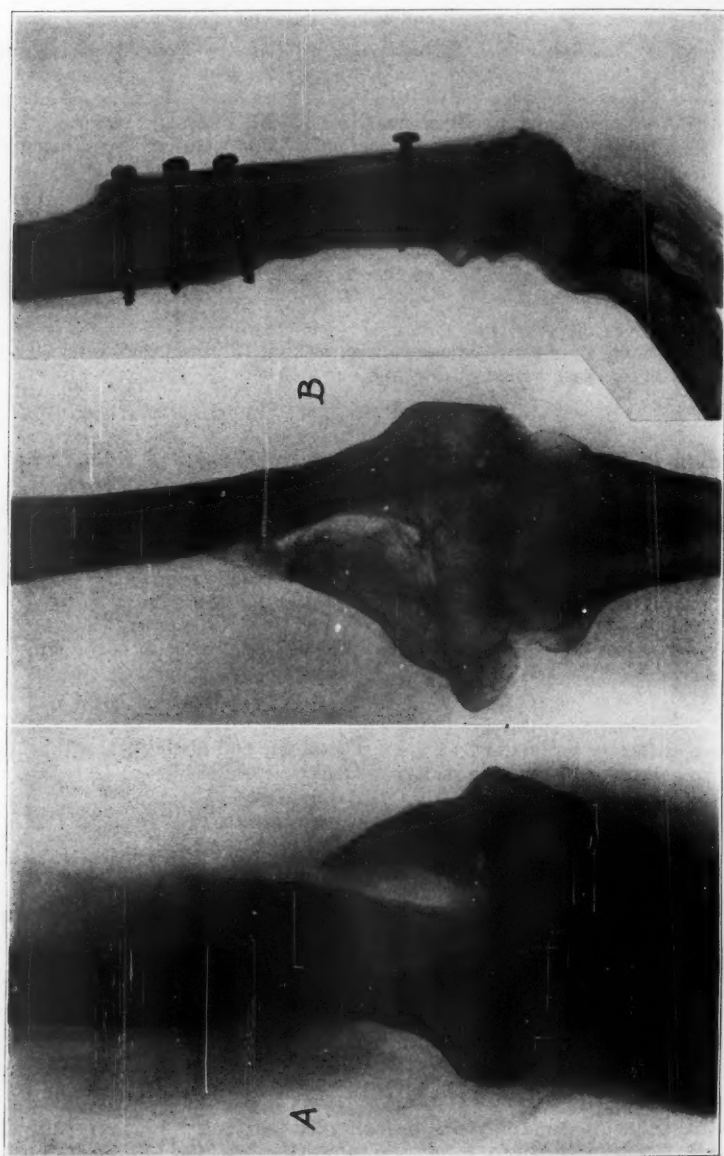
Fig. 4.—A. Ununited fracture of the humerus of 10 months' duration, secondary to a compound fracture followed by gas gangrene and staphylococcic osteo-myelitis.

B. One year and eight months after bone graft which utilized the shaft of the fibula. No flare-up of infection following the graft.

treatment of the wound without the impediment of cumbersome external fixation.

Since the possibility of infection in a fresh compound fracture is commensurate with the degree of laceration and maceration of the soft tissues, the 50 fresh compound fractures were further divided into mild, moderate or severe. Those fractures with small wounds formed by penetration of the soft tissues from within by the bone fragments were regarded as mild. Of the 10 cases in this group only 1 became infected, and in this case open reduction and internal fixation with an autogenous bone peg was employed. Prior to the use of sulfa-drugs, one could reasonably expect healing of the wound without infection in this type of fracture in a large percentage of the cases; consequently, an incidence of only 10 per cent infection in this group does not necessarily indicate a beneficial prophylactic action of the sulfa-drugs.

The group of moderate fractures were those in which the laceration was extensive incident to protrusion of the bone fragments through the soft tissues, but wherein little or no dirt or foreign material had been introduced into the wound. Of the 17 moderate cases, internal fixation was employed in 10; no internal fixation in 7. All united except 2; in both of these internal fixation was employed. The third group, severe fresh fractures, consists of those cases with extensive lacerations, penetrating wounds from without, considerable extraneous foreign material in the wound, and maceration of the tissues which necessitated extensive block debridement. Shotgun wounds with wadding and bird shot in the soft tissues might cause such a fracture. As would be expected, a great proportion of non-unions and a great proportion of infections were present in this group. The results are illustrated in table 2.

There was little difference in the average period of union between those with and without fixation. The chief advantage of internal fixation lay in the fact that better anatomic alignment could be secured and maintained, apparently, with a slightly greater risk of non-union or infection, but a smaller number of mal-unions. Even in the presence of infection or non-union, or both, malposition and shortening were not sequelae when internal fixation was utilized. Furthermore, less extensive forms of external immobilization could be employed, enabling the soft tissue wound to be observed and treated more efficiently without fear of displacing the fragments.

COMPOUND FRACTURES OF 24 HOURS' TO 3 WEEKS' DURATION

Nine patients in this series received treatment 24 hours to 3 weeks after the initial injury. In some instances an acute fulminating in-
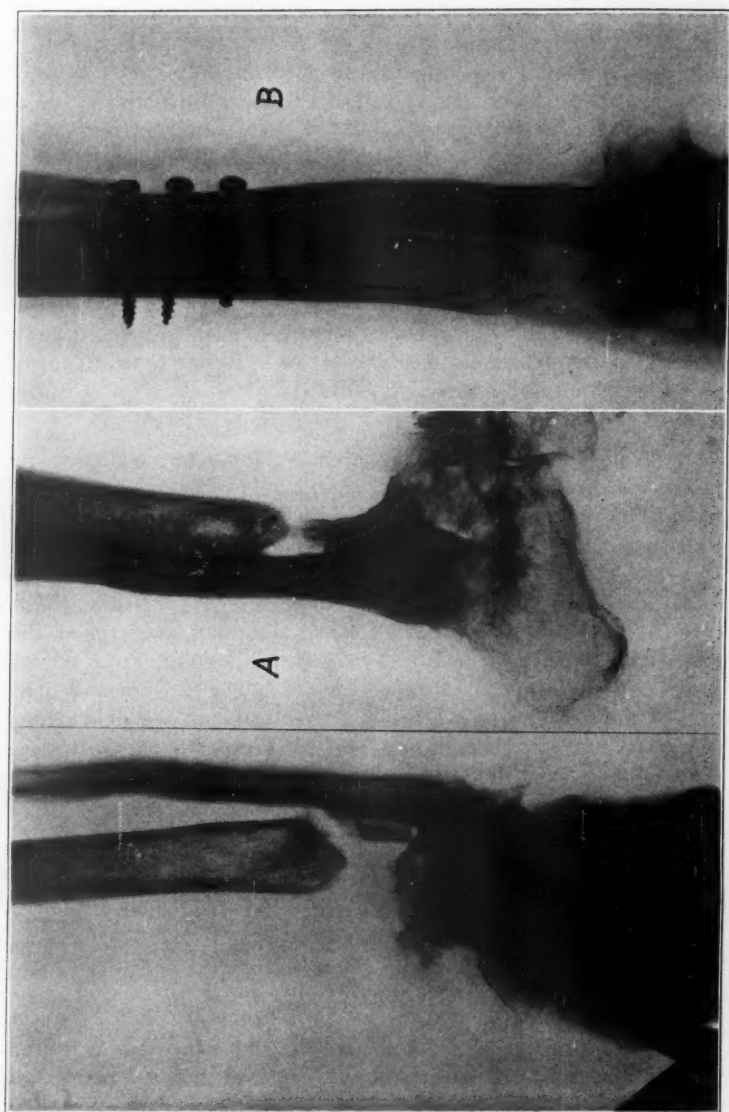
Fig. 5.—A. Two years after an old compound fracture. The lower end of the tibia sequestrated and necessitated its removal. There was a depressed scar about one inch deep over defect.

B. Two years after a two-stage transplantation of the fibula into the tibia above and into the astragalus below. Primary healing following both operations.

fection was already established. The wounds in all instances had been present sufficiently long that a relative degree of sterility of the wound by mechanical washing with saline solution was an impossibility. In most instances an en masse dissection of the soft tissues was necessary. The results, as one would expect, were very poor as illustrated in table 3.

COMPOUND FRACTURES WITH ACTIVE INFECTION

In this group active infection and draining sinuses often associated with a mild elevation of temperature had existed for from three to nine months. Previous to the use of sulfa-drugs treatment would
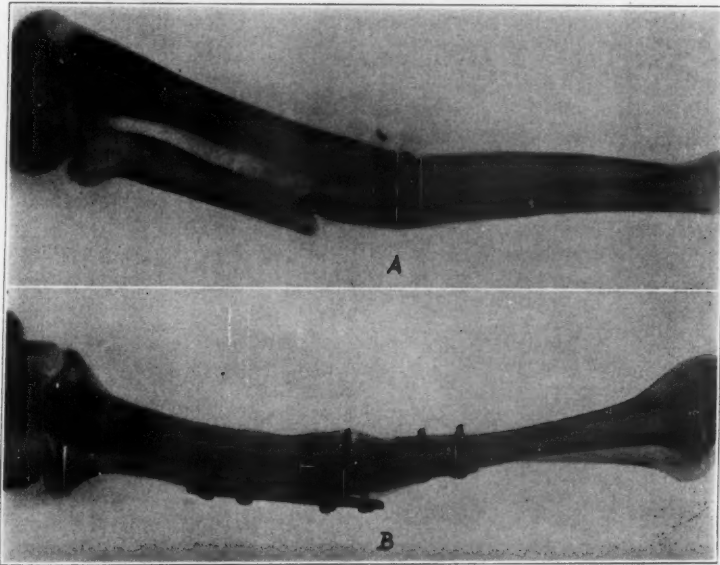
Fig. 6.—A. Compound fracture of both bones of the forearm in the middle third with active draining infection and multiple draining sinuses five months after an operation elsewhere. Following preoperative administration of sulfanilamide therapy, sequestra and wires were removed, fractures reduced, and vitallium plates applied. Active infection subsided in four weeks.
B. Six months postoperative.

have been directed toward healing of the infection; then, six months to one year after the active infection had entirely subsided and the soft tissue wounds healed, reconstruction procedures would have been instituted. Instead, open reduction and reconstruction procedures for malposition with delayed union or non-union, with and without internal fixation, were instituted. Draining sinuses were dissected out, sequestra and detritus were removed from about the

fracture site and, following replacement of the fragments, the soft
tissues were loosely closed. Internal fixation utilized in this group
consisted of plates, 6; nails, 4; wire loops, 1; no internal fixation, 2.
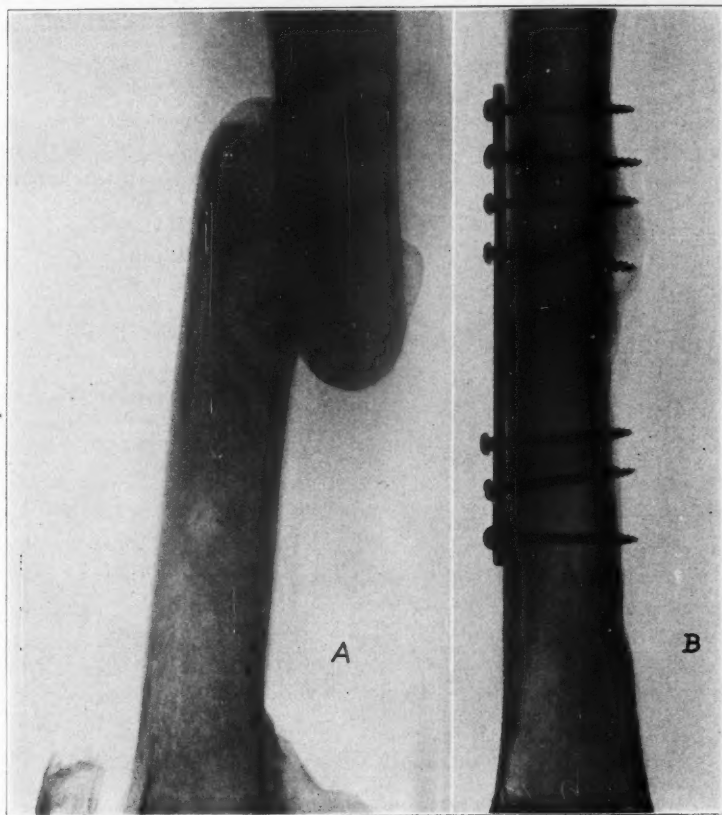There were no undue or prolonged febrile reactions following op-

Fig. 7.—A. Fracture of the femur of seven months' duration with multiple drain-
ing sinuses and large granulating wounds over the thigh from loss of skin surface
secondary to a mangling injury. Sulfanilamide administered before skeletal trac-
tion; open reduction and application of a vitallium plate carried out in the face
of an active infection.

B. Eight months later. All wounds had completely healed and the femur was
solidly united.

eration. Draining sinuses persisted in a number of cases for weeks,
but the wounds ultimately closed. In the two cases in which non-
union persisted, the vitallium plates had to be removed before healing
of the soft tissues eventuated. In another instance, after the wounds
had completely healed and union had been established, a plate was

removed because of pain. The results secured in these fractures with active infection were the most striking of the entire group in which sulfa-drugs were administered. No control group can be secured for a comparative analysis, as such radical surgery has not been previously performed. Such a procedure previous to the use of sulfa-drugs would certainly have been attended by a relighting of a more serious infection, and have defeated the purpose of a reconstruction procedure. Better functional and anatomic results were secured in a shorter space of time by these measures than by the previous routine of long delay while the infection healed. The series, however, is too small to be conclusive. The results are demonstrated in table 4. Sulfa-drugs were administered prior to the operation and, recently, sulfanilamide was placed in the wound and then administered by mouth postoperatively.

COMPOUND FRACTURES WITH LATENT OR POTENTIAL INFECTIONS

In 18 cases with latent or potential infection, extensive operations were employed as illustrated in table 5. To be eligible for this group, a case must have been a compound fracture in which an active infection developed with persistent drainage for a minimum of two months. The average amount of drainage of the cases that did not become infected was 5.4 months, and of those that did become infected, 7.7 months. Many of these cases would have been dismissed previously with no thought of surgery, and would have had to be content with considerable functional disability rather than to take the chance of relighting a severe infection with disastrous results. While no control group could be secured from our past records that is exactly comparable, we do have a series of cases which closely parallels this group. In 1939 an analysis was made of 261 onlay bone graft operations; 55 of these had been gunshot or compound fractures, and 24 of these had postoperative infection following a bone graft procedure. A similar analysis was made of arthroplasties performed on joints that had had infections introduced from without into the joint. Of these, 50 per cent developed an infection following operation. In the above series of 16 cases, one could certainly expect at least 50 per cent infection under the previous routine. With sulfa-drugs the number of infections was 25 per cent. All of the infections were staphylococcic. Internal fixation was used in this group as follows: vitallium plates, 4; vitallium screws, 1; bone grafts secured by vitallium screws, 8. Of the 4 infected cases, 2 were bone grafts and 2 were arthroplasties. Reankylosis occurred following the infection in the arthroplasties; 1 of the bone grafts proceeded to heal and eventuate in a union; the other still has a persisting draining sinus with non-union.

Case Reports

A. Moderate Compound Fractures:

CASE 1.—Mrs. D. S. C., aged 52, was seen four hours after receiving a Monteggia fracture and Colles' fracture of the same arm, with ulna compound in middle third. The ulna was exposed through an incision including the compound wound, reduced, and held by a vitallium plate and four vitallium screws. Through a separate incision, the head of the radius was reduced and orbicular ligament repaired. The Colles' fracture was reduced by manipulation and a plaster-of-Paris cast applied. Wounds healed without infection and all fractures were solid at the end of six weeks. One year later the patient had normal flexion and extension of elbow, normal pronation, and 85 per cent supination.

B. Severe Compound Fractures:

CASE 2.—Mr. M. A., aged 35, was observed five hours after a traffic accident; he had sustained an extensive compound fracture of the proximal end of the right tibia with six inches of bone exposed below the fracture site. The wound was debrided, the tibial fragments were reduced, and position was maintained by 1 vitallium pin and 1 stainless steel wire loop. The wound was closed loosely and plaster-of-Paris cast applied. Culture from site of the fracture was positive for Streptococcus hemolyticus and a gram negative bacillus. Sulfanilamide was given for 12 days, at which time temperature subsided. There was mild seropurulent drainage from the wound for several weeks and a small sinus persisted for four months. At this time, a sequestrectomy was done and metal fixation removed. Sulfanilamide was administered postoperatively for 10 days. The wound healed in three weeks and union was solid in eight weeks thereafter.

CASE 3.—Mr. O. H., aged 30, eight hours prior to admission, had been injured by explosion of a "laundry stove." He suffered a comminuted compound fracture of tibia; also a simple transverse fracture of the fibula. The fibula was exposed through a clean incision, reduced, and held by vitallium plate and 4 vitallium screws. Then, the compound wound over tibia was debrided and irrigated with saline, and fragments approximated with bony deficiency in anterior cortex. The wound was closed. Sulfanilamide was administered for five days when fever subsided. There was never any evidence of local infection and wounds were completely healed in two weeks. Union was present in two months, but a leather lacer brace was worn for five more months on account of tibial defect.

C. Latent or Potential Infected Compound Fractures:

CASE 4.—Miss A. J. G., aged 29, in September, 1936, had received extensive fracture-dislocation of left ankle which was debrided, washed with weak lysol solution, vaseline gauze drain inserted, and plaster-of-Paris cast applied. No sulfanilamide was given.

Legend to Figure 8 (continued)

B. Astragalectomy carried out in the face of an active infection. Denuded surface of the os calcis was approximated to denuded surface of tibia. Apposition of surfaces maintained by a long Steinman pin passed upward through the os calcis into the tibia.

C. Six months later. All wounds healed. No motion in the ankle joint. Satisfactory weight bearing member.
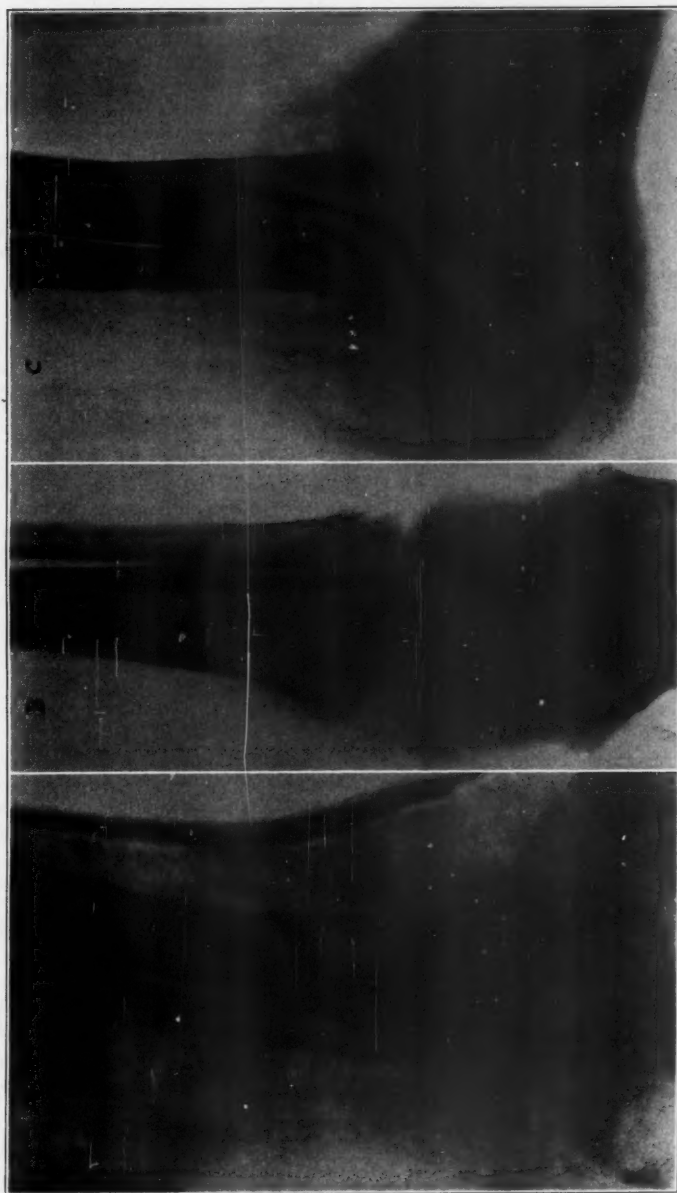
Fig. 8.—A. Sequestration of astragalus and loss of both malleoli five months after a compound fracture-dislocation of the ankle.

On Feb. 16, 1937, with the wound still draining, sequestra, which consisted of lower one to one and one-half inches of tibia, were removed and the wound packed with vaseline gauze. Drainage continued for five months, then wound healed. On June 17, 1938, deeply depressed and adherent scar tissue over defect in tibia was removed through an elliptical incision. A supramalleolar osteotomy of the fibula was done, and the fibula transplanted to the talus without shortening the leg, thus compensating for the distal end of tibia which had been excised. Sulfanilamide was given for six days. The incision healed by primary intention and union was solid in three and one-half months. On July 12, 1939, the fibula was osteotomized in the lower third and transplanted into tibia, being held by 3 vitallium screws and 1 wire loop. The incision healed by primary intention. Union was solid at the end of four months.

CASE 5.—Ten months prior to admission, Mr. A. L. R., aged 49, had sustained compound fractures of the humerus, left patella and left femur. A gas gangrene infection developed in the arm with osteomyelitis of the humerus. The femur united in malposition and he had a 2 cm. diastasis of the patella. On Sept. 13, 1938, sequestrectomy was done: this consisted of removal of distal 3 inches of shaft of the humerus down to condyles of the humerus. The wound was packed with vaseline gauze. Sulfanilamide was administered in routine manner. Three months later the wounds healed. There was loss in continuity of the shaft of about 3 inches, with wide deficiency in the bone. On April 7, 1939, fibular graft 6 inches long and held by 6 vitallium screws was used to bridge the defect in the distal end of the humerus. The patient was given the usual dose of sulfanilamide, 6 Gm. during 24 hours prior to operation and for four days postoperative. Incision healed by primary intention and moderate callus formation was evident at the end of two months. The patient was last observed on May 1, 1940. The arm was strong and solid, and he had no pain. Elbow was ankylosed at 150°.

D. Active Infected Compound Fractures:

CASE 6.—Mr. H. I. R., aged 43, was observed on Oct. 7, 1939 with a history of having had an open reduction and wiring of both bones of right forearm five months previously. The wounds had become infected and drained ever since, two operations having been performed subsequently to establish adequate drainage. Examination on admission: Multiple draining sinuses over both sides of forearm with profuse seropurulent discharge; marked bowing of fractures; pronation and supination of forearm nil with flexion of elbow limited to 45°, extension to 170°. X-ray showed old fracture with wire loops and small sequestra at site of fracture in both bones. Oct. 10, 1939, sinuses and adjacent scar tissue were excised, wire loops and small sequestra removed, and fractures reduced and held by vitallium plates with vitallium screws. Vaseline gauze drains were inserted and plaster-of-Paris cast applied. Culture from fracture site positive for hemolytic streptococcus. The patient received 6 Gm. of sulfanilamide preoperatively and the same dosage was continued for six days postoperative.

After mild serous drainage for about four weeks, the wounds healed and the fracture of radius was solid clinically and radiographically at the end of three and one-half months. Ulna showed good callus formation with all evidence of uniting. On April 6, 1940 union was perfectly solid in both bones, and the patient resumed his normal duties as manager of a hardwood lumber company.

CASE 7.—Mr. J. M. R., aged 32, received a compound fracture of the left astragalus and both malleoli six months previously. The wound continued to drain and, one month after injury, counter drainage was established on opposite side of ankle and both wounds have continued to drain ever since. On admission, the foot and ankle were markedly swollen and there was profuse purulent drainage from large sinuses just under both malleoli. X-ray revealed a nonviable astragalus. On Oct. 21, 1939, the astragalus and fractured portion of both malleoli and all infected sequestra were removed. The foot was displaced backward; os calcis was held in contact with the tibia by a Steinman pin passed from the plantar surface through os calcis and into the tibia. Sinuses packed with vaseline gauze. Culture showed hemolytic staphylococcus. Sulfanilamide given in customary dosage for eight days postoperative. On Dec. 1, 1939, the Steinman pin was removed and the cast changed. There was no motion at ankle joint. The sinuses had ceased to drain and healthy granulation tissue filled the wounds.

On April 8, 1940, the ankle had solidly fused; the patient was walking in leather lacer boot brace.

CASE 8.—Mr. W. L. B., aged 40, was observed seven months after compound fracture of right femur in middle third. The fracture was treated for 15 weeks by well-leg traction, then plaster-of-Paris cast with adhesive traction applied. Examination: Non-union of femur with marked overlapping of fragments and multiple sinuses over lateral side of thigh with a moderate seropurulent discharge. On Nov. 20, 1939, Kirschner wire was inserted through lower femoral metaphysis; the leg was placed in Hodgens splint with 15 pounds of traction. Roentgenograms one week later showed the overlapping and shortening had been corrected. A plaster-of-Paris body cast was applied incorporating the Kirschner wire, to permit a few days' rest. On December 2, the Kirschner wire was removed and sinus tract excised along with several small sequestra. The fracture was reduced and reduction maintained by a vitallium plate and 7 vitallium screws. Plaster-of-Paris body cast was applied. Culture taken at time of operation showed Staphylococcus aureus and Bacillus proteus. Sulfanilamide given in the usual dosage for three days preoperative and continued until patient had received 122 Gm. Fever gradually subsided and drainage of a seropurulent nature continued for about eight weeks. On Jan. 30, 1940 union clinically solid, probably accounted for in part by plate, but x-ray showed callus formation at site of fracture. Leather lacer body brace applied and patient allowed to walk. On May 2, 1940, femur showed solid bony union and patient walking.

Unusual care has been exercised in the evaluation of our results from sulfa-drug therapy in the treatment of the various groups of compound fractures in this survey. While the investigation has been as complete and unbiased as possible, correlation of all of the many variations was impossible; certain impressions that have been gained are definite but still are not conveyed by the statistics in the tables. In not one instance of the 21 infected cases, or cases in which infection was exacerbated, could the infection be considered severe, as compared with infections prior to the use of sulfa-drugs other than for the three cases of gas gangrene and the bacillus chauvaéi infection. Most of the cases listed as infected did not run a febrile course; nor were there copious quantities of purulent material exud-

ing from the wound for weeks, associated with emacation, anemia and sepsis, that would previously have been anticipated. It was also striking that drainage was not as persistent and that wounds in infected cases healed in a much shorter period of time than one would expect. We anticipate an even greater improvement in this series as combinations of sulfanilamide and sulfathiazole are used.

CONCLUSIONS

1. The use of sulfa-drugs in the treatment of fresh compound fractures has decreased the incidence of infection 10 per cent.

2. Primary healing of mild fresh compound fractures obviously is disregarded as evidence of favorable action of sulfa-drugs. In the severe and moderate types of compound fractures reported herein, certainly better anatomic and functional results were secured by internal fixation in conjunction with sulfanilamide without seriously increasing the proportion of complications, such as non-union and infection.

3. Primary closure of the wound has not increased the incidence of gas gangrene.

4. Neoprontosil and sulfapyridine have been discarded from the chemotherapeutic armamentarium. So far, the combination of sulfanilamide in the wound and sulfathiazole by mouth seems to be the most desirable, considering all factors.

5. Internal fixation in conjunction with the sulfa-drugs was well tolerated in the face of active and potential infections.

6. The beneficial action of sulfa-drugs was most striking in the group of actively infected fractures in which radical surgery had previously led to disaster.

7. In 18 cases with potential infection following infected compound fractures, extensive surgery was followed by more complete restoration of anatomic contour than had been possible in the past. In this group, only 25 per cent became infected with an anticipation of 50 per cent without sulfa-drugs.

8. The series of fractures with active infections and with potential infections is small, but the results are striking. The data, derived from a survey of the fresh compound fractures, are considered favorably impressive, but more extensive investigations will be carried out in the future with emphasis on the use of sulfanilamide and sulfathiazole alone, or in combination.

NON-PENETRATING TRAUMA OF THE ABDOMEN

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INJURY to the abdomen may result in either:

1. A laceration of the abdominal wall which does not penetrate the peritoneum.
2. A penetrating or perforating wound.
3. A contusion merely of the abdominal wall.
4. A contusion, laceration, or rupture of an intra-abdominal (non-penetrating trauma) organ or structure with no external injury.
5. Any combination of these four lesions (Levering).

Non-penetrating trauma of the abdomen may, therefore, cause simply a contusion of the abdominal wall, or laceration or rupture of any of the intra-abdominal viscera or blood vessels either without external injury, or with occasionally a superficial non-penetrating laceration. The uncertainty of the actual intra-abdominal lesion presents a problem in diagnosis and treatment of fascinating interest.

Successful treatment to obtain eventual recovery depends upon:

1. Prompt recognition that an intra-abdominal lesion is present.
2. Prompt decision that an operation is necessary.
3. The correct time for and method of operative interference.
4. The magnitude of the injury. With multiple extensive injuries, early or immediate fatality may be inevitable and the injured obviously beyond the aid of any treatment.

MORTALITY

It is to be remembered that mortality in trauma to the abdominal viscera is high due chiefly to the frequency of multiple major injuries. According to Petersen (Just[11]), from 1885 to 1890 it ranged from 60 per cent to 70 per cent, by 1900 it had decreased to 30 per cent. More recently, from von Eiselberg's Clinic, Demal (Lewis and Trimble[13]) reports in 126 cases a mortality of 13.9 per cent. This decrease in mortality seems due to improvement in diagnosis, and better recognition of the therapeutic indications, particularly the indications and time for operation.

INCIDENCE

The incidence of subcutaneous trauma of the abdomen as compared to injuries elsewhere in the body is low. In a five year period

2217 injuries of all types were admitted to our clinic, only 32 (1.4 per cent) of which had subcutaneous or non-penetrating abdominal trauma. Cody[4] reports similarly 5744 accidental deaths in Iowa during a three year period 53 (0.9 per cent) of which were the result of subcutaneous abdominal trauma. This type of injury, therefore, may not be frequently encountered except in hospitals devoted largely to traumatic surgery.

ETIOLOGY

Abdominal trauma may result from:

1. An anteroposterior or a lateral squeezing, or a direct blow, crushing a viscus between the instrument of force and the spine.
2. A tangential force, moving the bowel beyond its limits of mobility, causing tears in the mesentery.
3. Compression of fluid or gas in a single loop of intestine.
4. Fragments of fractured pelvic bones, rupturing or puncturing the bladder or rectum.
5. Falls at play, at work, or in the house.

Motor and industrial accidents, athletic injuries and falls in the home are the most frequent causes. Of Bailey's[1] 100 cases, 76 were due to transportation accidents (60 motor), the remaining 24 to industrial or athletic accidents, or falls in the home.

PATHOLOGY

In mild cases without evidence of superficial contusion of the abdominal wall, there may be a hematoma deep in the muscles, a laceration of the deep epigastric artery, a retroperitoneal hematoma, hemorrhage into the mesentery or omentum or beneath the capsule of liver, spleen, or kidney, or beneath the serosa of stomach or intestine. It is this group that definitely may be treated conservatively. The frequency with which mild indeterminate trauma is found has been variously reported; in 45, (30 per cent) of 140 cases by Lewis and Trimble[18]; 41, (54 per cent) of 76 cases by Just[11]; and 36, (38 per cent) of 94 cases in our series.

Crushing and severe injuries commonly produce laceration or rupture of the liver, spleen, pancreas, or kidney; small or large intestine, stomach, diaphragm, bladder, gallbladder, omentum or mesentery. Numerous reports of obscure and rare lesions have also been recorded such as:

1. Hemoperitoneum due to subcutaneous rupture of the iliac vein.
2. Thrombosis of a mesenteric vein.
3. Rupture of a gastric ulcer.

4. Avulsion of the gallbladder.

5. Tuberculous peritonitis, following rupture of an intraperitoneal tu-
   berculous abscess.

DIAGNOSIS

The successful outcome of most cases hinges upon the sagacity
and diagnostic acumen of the attending physician. Clinically, ab-
dominal trauma may be classified into three groups.

1. Severe multiple injuries which are rapidly fatal and for which no
   treatment is of avail.

2. Cases that obviously require immediate operation.

3. Cases in which the diagnosis is doubtful and the indications for or
   against operation are not clear.

In the proper care of this third group lies the greatest oppor-
tunity for saving lives and lowering the extraordinarily high mor-
tality rate. Very close and repeated observation is mandatory. At
the earliest possible interval following the accident, a decision must
be reached whether the lesion demands immediate operation or not.

Aids toward an accurate diagnosis will be:

1. The history.

2. Careful physical examination.

3. Blood count, and blood protein estimations, and urine examinations

4. Radiograph.

I. HISTORY

It seems generally agreed that force applied to a *limited* or *cir-
cumscribed* area of the abdomen is more prone to lacerate or rup-
ture the intestine or kidney, but force applied diffusely over a wide
area is likely to injure the liver, spleen, pancreas, bladder, or blood
vessels. Engorgement or dilatation during physiologic activity may
predispose to injury. It is important, therefore, to know the exact
character of the blow, the size of the object inflicting the injury, the
details of the accident, the time that has elapsed since the accident,
and the previous consumption of food or drink. Therefore, a de-
tailed and accurate history should be obtained, which should include
an account of any previous abdominal disease.

II. EXAMINATION

The examination of the patient should be thorough and pains-
taking with consummate weighing of the evidence. The pulse and
blood pressure should be noted; a patient with pallor should sug-
gest hemorrhage or primary shock. One of the deceptive features

of abdominal trauma is that the primary shock may be transient. If the patient is in shock, a detailed examination must be postponed until treatment for its relief has been effective. However, the examination, when made, should be complete for injury not only of the abdomen, but of other parts of the body, as multiple injuries are not infrequent.

Abdominal distension or meteorism, localized pain and tenderness, muscle rigidity or spasm, and absence or presence of peristalsis and the type of respiratory excursion must be carefully studied. Early abdominal distention with general abdominal, but not boardlike rigidity and absence of severe pain, particularly if there is evidence of a concomitant back injury, are indications of injury or irritation of the coeliac plexus, and that a conservative policy can be planned. *Increasing* abdominal distention with localized tenderness and rigidity—often boardlike—severe *persistent* or recurrent pain, and absence of peristalsis, are indications of a visceral injury, and for immediate operation. Rectal or vaginal examination, particularly when the lesion is in the lower abdomen, may prove of great value. By this procedure, a retroperitoneal rupture of an air-containing viscus may be recognized when palpable emphysema of the pelvis is present.

Either continuous or intermittent pain that is *persistent* and *repeated* vomiting or hematemesis are particularly significant. Vomiting, in itself, is not pathognomonic, but repeated vomiting, or repeated hematemesis and persistent pain may be evidence of visceral injury.

One should not be deceived by a post-traumatic period of comparative comfort or relative normalcy. Years ago (1858), Polland noted in certain instances of grave abdominal trauma, "the absence of all symptoms *indicating a mortal injury* for upward of two hours." Butler[3] observes that with shock or alcoholism this interval may be lengthened to six or eight hours. Cases of laceration of the intestine, stomach, bladder, and spleen have been recorded in which the patient has walked and shown no evidence of major casualty only to collapse at a later interval[14].

III. Blood Count and Laboratory Tests

Immediate, complete blood count and urine examination should be made. Bloody urine indicates kidney, bladder, or urethral injury. In cases where shock is present and hemorrhage suspected, estimation of the blood specific gravity by the falling-drop method of Barbour and Hamilton, as Bailey[1] has suggested, can be rapidly made, the concentration of blood plasma protein quickly determined

and prompt information obtained as to whether hemorrhage has occurred. By this means, true or simple shock may be differentiated from that due to hemorrhage. The estimation of blood concentration, if desired, can be checked by hematocrit determination.

IV. RADIOGRAPH

A procedure that is of distinct value in the diagnosis of *intestinal* laceration or rupture is a radiograph of the abdomen. White[21] has suggested that this be taken in the sitting posture so that free gas in the peritoneum can be better recognized by its concentration beneath the diaphragm—a crescent or sickle-shaped gas accumulation over the liver and below the diaphragm. If the patient cannot sit, White[21] advises a lateral x-ray at the level of the diaphragm with the patient prone. Gas beneath the diaphragm when present is positive evidence of intestinal rupture, but *if absent* or unrecognized it does *not rule out* the possibility of intestinal laceration.

SUMMARY

The evidence as elaborated by history, examination, laboratory tests and x-ray, must be carefully weighed. Abdominal examination is the most important. Severe localized or general persistent abdominal pain, increasing pulse rate, repeated vomiting, localized tenderness and boardlike rigidity, with or without evidence of increasing hemorrhage or infection form a combination that demands operative interference.

All cases, *no matter how trivial, in which a decision for operation cannot be immediately made, should be kept under the closest observation and opiates withheld.* Repeated examinations should be made *at least every thirty minutes,* until a definite conclusion concerning operation can be reached. In an obscure quiescent case, illuminating symptoms such as pain, distention, or rigidity may have a sudden onset. Blood pressure and pulse records should be taken every fifteen or thiry minutes. Blood counts should be repeated at short intervals. The repeated blood count may show evidence of hemorrhage by decreasing hemoglobin and red blood count and of advancing infection by an increasing leukocytosis. Decision for or against operation should be made within four to six hours after the accident. Any delay beyond this period may jeopardize the possibility of saving a life.

As Just[11] has stated, "In spite of the most painstaking study, there will always remain a number of cases in which a definite diagnosis is impossible, but the syndrome is of a type which *justifies operation.* In these cases, an exploratory laparotomy should be done."

V. Shock

Primary shock may be due to

1. Extremely painful trauma.
2. Severe crushing injury, or
3. Hemorrhage, (Butler).

It may be exceedingly difficult to distinguish which is the primary factor unless recourse is had to the determination of blood specific gravity and estimation of plasma protein. By this method, primary shock and that due to hemorrhage can be rapidly differentiated and the appropriate treatment indicated.

Shock is not a necessary accompaniment of every injury; moreover it shows wide variations which may not be at all correlated with the severity of the trauma. Shock should be combated promptly by application of heat, lowering of the head, intravenous infusions of saline and glucose, and gum acacia, or blood transfusion, and injections of eschatin, or adrenal cortical extract, and ephedrin. Morphia should be withheld until a decision concerning operation has been reached. *Immediate operation should not be undertaken until effort to relieve shock and improve the patient's condition has been made and a systolic blood pressure of 100 or over obtain⁓ᵈ. If uncontrolled hemorrhage is a factor, the improvement will not be long sustained.*

Jaki[10] distinguishes three stages of progression in severe abdominal trauma:

1. Shock.
2. Transient subjcetive improvement.
3. Collapse in the case of hemorrhage, or peritonitis in the case of perforation (injury) of a hollow organ.

VI. Treatment

The treatment of abdominal trauma may be classified as:

1. Conservative, or
2. Operative.

1. Conservative treatment is largely symptomatic but may require maintenance of fluid balance, and adequate blood concentration by appropriate intravenous therapy and transfusions especially when vomiting or hemorrhage recurs and particularly in preparation for late surgical intervention.

2. Operation may be indicated either early or late. Early operation should take place within six hours of the accident, particularly

when injury to hollow viscera is suspected. Late operation will be demanded by evidence of progressive or recurrent hemorrhage, extensive visceral damage or local tumor formation, indicating unresolved hematomas, local abscesses, or actual neoplasm (pancreatic cyst, etc.)

The most common intra-abdominal lesions are lacerations or rupture of the liver, spleen, kidney, intestine, and bladder. Their incidence, diagnosis and treatment will be considered in detail.

LIVER

Of all the abdominal viscera, the liver is most frequently injured, due to its large size and its limited range of mobility. The injury to the liver is usually a rupture or laceration, tearing the capsule, though a subcapsular rupture with destruction of liver parenchyma may occur. Squeezing trauma of the abdomen applied over a large surface, or falls from a height. the patient landing on his feet, are the usual causes of ruptured liver. Large ruptures are rapidly fatal. Injuries to the right lobe of the liver are more common than to the left[20]. The mortality is high, due to the frequency of associated injuries; these most commonly are fractures of the ribs and spine and lacerations of the diaphragm, stomach, and kidney. Edler (Lewis and Trimble[13]) finds a mortality of 50 per cent. Baker and Lecount also, in 384 fatalities from abdominal trauma reported the liver involved in 50 per cent. Death from liver trauma alone results from uncontrolled hemorrhage and bile peritonitis.

Due to the extensive hemorrhage caused by the liver tear there is always considerable shock. The symptoms are often obscure, but there may be severe abdominal pain, restlessness or delirium with marked tenderness and rigidity in the upper right quadrant and shallow respiratory excursion. The diaphragm may be elevated. Bradycardia has been reported by Finsterer[7], but only McKnight and Orth have corroborated this observation. In McKnight's case, the bradycardia occurred three hours after injury; six hours after the accident the pulse had returned to normal. Bradycardia in liver trauma may be transitory and cannot be of very frequent occurrence.

When the patient is not moribund and when there is definite evidence of unchecked hemorrhage, operation is indicated. Without evidence of severe and persistent hemorrhage the patient may be treated conservatively. Operation was found possible in 14 out of 20 of Lewis' cases, and 8 out of 10 in Just's cases. Transfusion may be necessary before, during, and after the operation. On exploration, if there is still bleeding from the liver this may be arrested by digital compression of the hepatic artery and portal vein at the

foramen of Winslow[3] and the laceration may be sutured or the hemorrhage controlled by *tamponade* and suture. Drainage should be instituted to facilitate the extra-abdominal escape of bile leaking from the laceration. If the hemorrhage seems controlled or has ceased, it has been suggested that the blood in the peritoneal cavity may be gently evacuated by suction, but clots in the rent in the liver had best not be disturbed as fatal and uncontrollable hemorrhage has occurred from over-zealous efforts to suture the laceration when hemorrhage has ceased. Suture, in this case, is not necessary, as spontaneous healing can take place. Trimble[13] has pointed out the danger of re-infusion or transfusion of the blood taken from the peritoneal cavity in rupture of the liver. Toxic symptoms may follow, and several fatal results have been recorded.

SPLEEN

A rather diffuse blow to the left abdomen or lumbar area is usual in splenic rupture, such as would result from a fall out of a window, landing on a concrete pavement, a fall across a railroad track, or from a thrown ball or brick striking the left abdomen. Conners[6] has remarked the frequency with which motor accidents may be the etiologic factor and the high incidence of splenic rupture in youth (70 per cent).

The laceration of the spleen may be stellate or almost a complete division or fracture, and permits very extensive hemorrhage. Rupture occurs quite readily because the splenic limiting membrane, or capsule, is fragile and thin, particularly in the young. Splenosis or multiple intraperitoneal implantations of splenic tissue have been found as a late sequel of rupture in the cases that recover[2].

The patient complains of either diffuse abdominal or severe upper left quadrant pain, sometimes pain in or under the left shoulder, and is usually in shock. It is this injury that so characteristically has an apparent spontaneous recovery from the primary shock which probably is due to a temporary arrest of hemorrhage only to pass into a terminal collapse that may be rapidly fatal when the hemorrhage recurs. Butler has suggested that the rhythmic contractions of the spleen may cause this recurrence. There is usually a rapid pulse with abdominal distention, marked tenderness and rigidity in the upper left quadrant, and vomiting. Pallor may not always be an early feature, but the hemoglobin and red blood count will show well defined anemia. The patient may be restless, even delirious. Increase in the pulse rate and a falling red blood cell count and hemoglobin or a decreasing blood protein are significant. Following abdominal trauma, acute pain and tenderness in the

upper left abdomen and shoulder with symptoms of hemorrhage is sufficient to justify a diagnosis of rupture of the spleen. Rarely, there may be a long latent period when the clot that forms in the splenic laceration controls the hemorrhage for several days. Unless a mass in the upper left quadrant can be palpated, rupture of the spleen can merely be *suspected* unless the procedure suggested by Pendergrass[16] is resorted to. He recommends giving the patient a seidlitz powder to outline the stomach. A radiograph is then taken. In splenic laceration in which a large perisplenic clot may have formed, temporarily controlling hemorrhage, an external pressure deformity of the gastric fundus may be demonstrable. In doubtful or suspicious cases, this procedure may be of value.

Mortality: The mortality and prognosis depends upon the severity of associated lesions, an early and properly timed operation and the extent of the laceration and hemorrhage. It is seldom less than 30 per cent in any reported series. Cases in which is found trauma of the liver, stomach, pancreas or ribs, are almost invariably fatal.

Treatment: If the patient's blood pressure is low, or he is in shock, a transfusion should be given. Operation should take place as soon as the blood pressure is over 100, and preparation should be made for a postoperative transfusion to follow. The intraperitoneal blood may be ladled or aspirated out into a sterile flask, citrated, and reinfused in a vein. This may often prove a life-saving measure. Spinal anesthesia has much to recommend it. Splenectomy is to be preferred to suture or tamponade of the laceration.

KIDNEY

Rupture of the kidney will result from railroad and motor accidents or a fall, striking the flank against a projecting object, a fall downstairs.

Trauma to the kidney may cause a simple subcapsular tear and hematoma, or extensive fragmentation with multiple lacerations of the parenchyma and capsule, rupture of the pelvis, or rupture or laceration of the renal vessels, with extensive retroperitoneal hemorrhage and extravasation of urine. There may be multiple associated injuries.

Hematuria is the constant and characteristic symptom. There is tenderness, occasionally muscle spasm over the lumbar muscles on the affected side, and at times a palpable mass in the renal region. There may be colicky pain down the course of the ureter due to passage of blood clot. With extensive laceration and retroperitoneal hemorrhage symptoms of shock may be present.

Most of the injuries to the kidney are contusions, heal spontaneously, and expectant treatment will suffice. However, in the remainder the capsule or pelvis is lacerated, operation will be necessary, and if deferred too long, may not save the patient. Just[11] reported that 7 of 23 cases, (30 per cent), of kidney trauma were treated surgically; Lewis and Trimble[13] 9 out of 30 cases. (30 per cent) ; Prather[18] 6 out of 20, (30 per cent) ; and Peacock [15] 6 out of 26 (23 per cent). The indications for operation are gross infection, persistent hematuria, evidence of urinary extravasation, loss of renal function. When hematuria persists over one week, with no evidence of cessation, there is a great likelihood of renal vessel injury or extensive destruction of the kidney.

Intravenous urography will help determine the extent of damage to the kidney and in doubtful cases may confirm the necessity for operation. Sterling (Henline[8]) found a satisfactory diagnosis could be made by excretory urography in 23 of 34 patients. Sargent[19] believes that a retrograde pyelogram is more accurate and is useful if intravenous urography gives inexact information. However, Peacock[15] has observed a fatal secondary hemorrhage produced by retrograde pyelography and considers this procedure dangerous. It would seem that a retrograde pyelogram should be resorted to with extreme caution, and only when indications for operation cannot be determined by other means.

At operation, suture of the kidney may frequently suffice, but nephrectomy will at times be indicated. Lewis[13] records a mortality of 5 out of 30—16 per cent. Prather[18] 4 out of 20—(20 per cent). In our series there were 6 deaths in 20, or 30 per cent. Just[11] reports no deaths in 23 cases. Again it is multiple associated injuries or too great delay in operation that largely determines the mortality.

INTESTINES

A circumscribed blow to the abdomen is the usual cause of intestinal laceration or rupture, such as a kick in the abdomen, trauma from a projecting bit of revolving machinery, or a fall against a projecting object. The upper jejunum and terminal ileum are most vulnerable as these loops can be compressed against the vertebral column by the traumatizing force. Rupture of the stomach is rare. In the large intestine, the sigmoid is most commonly damaged[9]. Not infrequently there is concomitant laceration of the mesentery or omentum, and at times subcutaneous rupture of the abdominal wall. A bursting or hydraulic rupture of the intestine is sometimes found, which is usually a long laceration and involves a considerable segment. Polland referred to 123 intestinal injuries of which 6 were

in the duodenum, 44 in the jejunum, 38 in the ileum, 31 of the mesentery, and 4 in the colon (Butler). Of Wyss' 39 cases, 5 were in the duodenum, 32 in the jejunum and ileum, and 2 in the large intestine (quoted by Lewis and Trimble[13]). Jaki[10] found of 16 cases, 13 in the ileum, and 3 in the jejunum. Nevertheless, jejunal injury in general is considered more common.

There is usually an initial shock and the patient complains of severe abdominal pain. However, numerous instances have been recorded when the injured person has been able to walk after the accident and has so little distress he refuses hospitalization or treatment[13]. This is probably due to a temporary plug of the intestinal opening. All cases of abdominal trauma, therefore, no matter how apparently trivial, should be hospitalized and kept under the closest observation[14].

Following definite rupture there are severe abdominal pain, usually continuous, increasingly rapid pulse, repeated vomiting, general or localized abdominal rigidity—usually boardlike abdominal distention, symptoms and signs of a spreading peritonitis. In doubtful cases, the diagnosis may be confirmed by the history, increasing leukocytosis, demonstration by roentgenogram of free air in the peritoneal cavity, and the development of characteristic symptoms under observation. If there is a reasonable probability of intestinal injury and the patient's condition is satisfactory in the absence of a complete symptom and sign complex, exploratory laparotomy should be done.

Early operation after treatment of any initial shock is imperative and should take place within six hours of the accident, if possible. Mortality mounts rapidly with delay beyond this interval due to peritonitis. Spinal anesthesia facilitates the operative procedure, which should be carried out as rapidly and gently as possible. Suture of the laceration is usually sufficient; this is best done transversely (as in the Mikulicz operation), rather than longitudinally. With extensive mesenteric laceration, resection may be necessary. In desperate cases, obstructive resection or colostomy, particularly in large intestinal rupture, may be indicated. Postoperative sulfanilamide therapy should be used routinely, preferably by hypodermoclysis (8 Gm. in 1000 c.c. of normal saline solution) unless oral or intravenous administration seems more desirable. Sulfanilamide may be administered also to patients under observation in which rupture of the intestine is suspected.

The reported mortality is surprisingly high: Petry[17] reports 199 cases with a mortality of 87.5 per cent. Hertle (Lewis and Trimble[13]) reports 138 cases with a mortality of 76.8 per cent. Lewis[13]

reports 11 operative cases with 62 per cent mortality. Our series of 19 cases had a 58 per cent mortality and Just's 11 cases 9.99 per cent mortality. However, all of Just's patients were without other associated injuries.

The high mortality is due to peritonitis, delayed operation, large and multiple lacerations, extensive hemorrhage, and to associated injuries, particularly laceration of the mesentery. Early diagnosis and operation, as Just points out, will tend to decrease what would seem to be an extraordinarily high mortality.

BLADDER

Rupture of the bladder follows a crushing injury of the lower abdomen usually in the anteroposterior direction, or a blow or kick over a *distended* bladder. A squeeze between two railroad cars, between the wall of a building and a moving object, or abdominal compression in a motor accident are all characteristic instances. There is frequently a fracture of the pelvis associated, but the rupture of the bladder is seldom actually caused by the fracture; there may be injury to other pelvic viscera and blood vessels.

The rupture of the bladder may be extraperitoneal or intraperitoneal; the latter is likely to be from the bursting of a bladder, distended at the time of injury. In extraperitoneal rupture there will be swelling and tenderness and pain in the suprapubic region and, as extravasation of urine takes place, the swelling will spread to the inguinal regions. There will be strangury. The patient will void only small amounts of bloody urine or none at all, and the catheter will withdraw but a small amount of bloody fluid. In a doubtful case, a cystogram with a measured amount of fluid (5 per cent sodium iodide) or air should clear up the diagnosis. Intraperitoneal rupture will give the symptoms of a rapidly spreading peritonitis, but Lewis cites instances of remarkable delay in their onset. At times, symptoms of fracture of the pelvis may overshadow or conceal those of a bladder injury. There may be severe shock with concomitant pelvic injury.

The mortality in rupture of the bladder is reported by Peacock, of 14.4 per cent, (4 deaths in 28 cases); by Culver and Baker[6], 6.25 per cent (1 death in 16 cases). Mortality results from the association of other severe injuries, massive hemorrhage from laceration of large pelvic blood vessels and delay in operation. Early recognition of rupture and early operation is imperative. Suture of the rent in the bladder, control of hemorrhage and drainage will be necessary. Postoperative sulfanilamide or sulfathiazole therapy will be advisable.

CONCLUSION

Non-penetrating trauma to the abdomen may result in an injury that may be treated either:

(a) Conservatively, or by

(b) Operative interference.

Successful treatment depends upon:

1. Prompt recognition that an intra-abdominal lesion is present.

2. Prompt decision that an operation is necessary.

3. The correct time for and method of operative interference.

4. The magnitude of the injury.

Clinically, the cases may be classified into three groups:

1. Severe multiple injuries which are rapidly fatal and for which no treatment is of avail.

2. Cases that obviously require immediate operation.

3. Cases in which the diagnosis is doubtful and the indications for or against operation are not clear.

The history, careful physical examination, repeated blood counts, blood specific gravity and blood protein determinations, urine examination, and radiograph of the abdomen should be helpful in establishing the diagnosis. *In doubtful cases only by frequent repeated re-examination (thirty minute intervals) will the early evidence of a serious lesion be recognized in time to suggest operation before it is too late.* Every case of abdominal trauma, therefore, no matter how apparently slight, should be kept under close observation until a sufficient interval has elapsed to determine whether an operation is indicated or not, or until recovery is assured. Lesions of the hollow viscera will demand early operation. Solid visceral injury, unless accompanied by persistent and unrestricted hemorrhage may more properly be considered candidates for delayed or late operation. Only by close constant supervision and the prompt recognition of an intra-abdominal catastrophe demanding operation can the extraordinarily high mortality in abdominal injury be lowered.

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THE MANAGEMENT OF PERFORATING GUNSHOT
WOUNDS OF THE ABDOMEN

Based on a Study of Three Hundred and
Sixty-nine Cases

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THE aggressive axiom which says, "Might makes right," seems,
at the present time, to dominate human conduct, and those na-
tions which are not actually fighting are hastily preparing the imple-
ments of war that deal out death and destruction. In an attempt to
counterbalance this unnecessary slaughter the medical profession
throughout the world is combining its efforts to relieve suffering and
prevent deaths resulting from war injuries.

The improvement in the end results of most traumatic conditions
has been an incentive for the doctors to redouble their efforts to save
lives and prevent disabling deformities. However, there is one con-
dition, namely, perforating gunshot wounds of the abdomen, in
which the mortality has not been greatly lowered during the past
twenty-five years, and therefore it remains one of the most serious
surgical conditions that confronts either the military or civilian
surgeon.

There has been such a radical change in the method of material
attack; with its parachute troops; quick striking mechanized units;
the bombing and machine gunning of towns hundreds of miles in the
interior, that much of the responsibility for the care of the injured
rests on the shoulders of the civilian doctor and hospital.

Since the mortality remains what it is, it is proper that the local
cases, as well as the literature, be reviewed to determine the factors
influencing that mortality. Also to study and analyze critically
the different methods of treatment so as to eliminate any procedure
that is bad and to salvage any procedure that seems to be good. So
let us in time of peace study this vital problem and be prepared for
any eventuality.

This review is based on a study of 369 cases of gunshot wounds
of the abdomen with visceral perforations occurring in Nashville
during the period of 1923-1940. In the 32 cases in which explora-
tion was not done there were 30 deaths, or a mortality of 93.7 per
cent. However, of 337 cases in which exploration was done there
were 204 deaths, or a mortality of 60.5 per cent. This operative

mortality is exceedingly high, but not far out of line with the mortality of other large series covering approximately the same period as covered by this study.

The type of weapon used, the age, sex, color of the patient, and the viscera or vessels perforated are all factors influencing the mortality which are beyond the surgeon's control. Nevertheless, we should have a thorough knowledge of the importance of these factors as an influence on the end results so that we may better plan our method of treatment and make a more accurate prognosis.

OCCURRENCE IN DIFFERENT AGE GROUPS
WITH MORTALITY
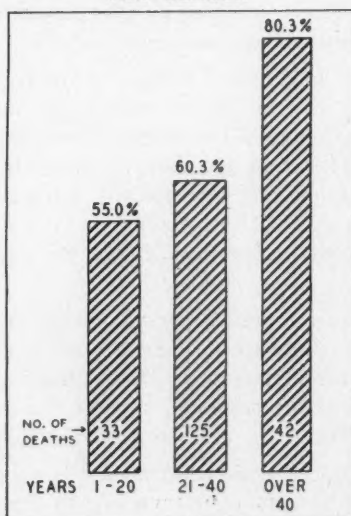
Chart 1. Graphic representation of mortality incidence in the different age groups.

The ballistics experts have discovered from a study of injuries produced by gunshot fire that the three factors which determine the amount of tissue damage are: first, the size; second, the velocity; third, the contour and composition of the missile. These observations have been partly substantiated in this review, for the mortality of 20 persons shot with a 0.22 caliber rifle was 40 per cent as against a mortality of 61.8 per cent of the 265 persons shot with a weapon of higher caliber. The highest death rate (80.5 per cent) was in the 36 individuals shot with shotguns. The higher rate in those injured by shotguns is contrary to other reports but can be explained on the grounds that most of these cases were attempted suicide shot at close range or else shot by police officers using buckshot. As a re-

sult of this, large holes were torn in the viscus which made repair almost impossible.

The stamina of youth to withstand shock and combat infection is clearly demonstrated in this study, which shows that the mortality increases steadily with the decades of life (chart 1). The cases were grouped in 20-year periods and compared, and the lowest rate was 55 per cent found in the group of 1-20; next, 60.3 per cent mortality occurring in the age group 21-40; and lastly a mortality of 80.3 per cent in those over 40 years of age.

AMOUNT OF HEMORRHAGE WITH MORTALITY
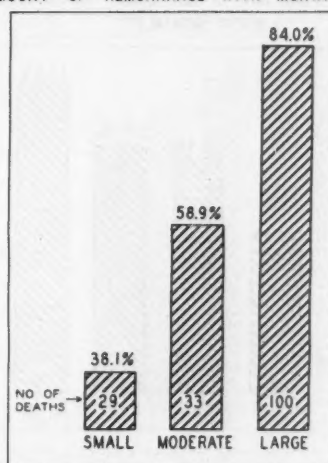
Chart 2. Graphic representation of the mortality based on the amount of hemorrhage.

The presence of blood in the peritoneal cavity was recorded in 251 cases. The amount of hemorrhage was divided into three groups; the small hemorrhage group 500 c.c. or less; the moderate hemorrhage from 500 to 1,000 c.c. and the large hemorrhage, 1,000 c.c. or more. The fatality rate increased steadily with the amount of hemorrhage (chart 2). In the 76 cases of the small hemorrhage group the mortality was 38.1 per cent; in the 56 cases of the moderate hemorrhage group the mortality was 58.9 per cent, in the 119 cases of the large hemorrhage group the mortality was 84 per cent. To emphasize further the importance of hemorrhage, 122 cases or 63.8 per cent of the total number of those dying, did so within the first twenty-four hours. This study shows convincingly that the amount of hemorrhage is the greatest individual factor in the mortality and therefore, the controlling of hemorrhage and restoration of blood volume is the greatest problem in the prevention of deaths.

Because of the normal variance of the bacterial content of the different organs, the viscus perforated is next to hemorrhage in importance as a factor in determining the death rate. The mortality increases when more than one organ is perforated, as the number of holes and degree of destruction of the organs increase and as the site of perforation descends in the intestinal tract (chart 3). The lowest mortality was in perforations of the liver, 40 per cent. The mortality gradually increased with descent in the intestinal tract, namely: stomach 52.9 per cent, small intestines 54.1 per cent,

PERFORATION OF DIFFERENT ORGANS
WITH MORTALITY
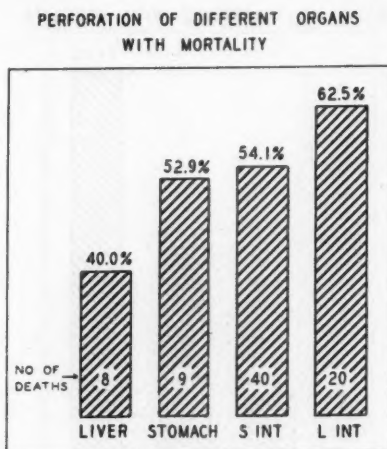
Chart 3. Graphic representation of the mortality in perforation of different organs.

large intestines 62.5 per cent. Unfortunately, however only 43 per cent of the total cases had perforations of a single organ. The small intestine was injured the most often, the average number of holes being 6.2.

In contrast to the uncontrollable factors influencing the mortality, are the procedures under the surgeon's control, namely: choice of anesthetic, operative technic, length of procedure, preoperative and postoperative management. The high mortality of gunshot wounds can be lowered by an improvement in the management of the controllable procedures. It is, therefore, essential that a thorough study of the statistics in this group be made so as to evaluate the findings and try to reach some conclusion as to the best way to manage perforating gunshot wounds of the abdomen.

The time elapsing from injury to the beginning of the operation was accurately tabulated, and the results showed convincingly the

advantage of early operation (chart 4). In those patients who were operated on within a period of two hours the mortality was 58.1 per cent and the fatality rate increased steadily with the elapse of time until within an interval of six to nine hours the mortality rate was 66.6 per cent. After nine hours the mortality was again lowered to 60 per cent. This reduction in the death rate was due to the fact that none in this group was in extreme shock suffering from large hemorrhage. The study showed that only 47.5 per cent of the total number of cases were operated on within a period of two

LENGTH OF TIME BEFORE OPERATION
WITH MORTALITY
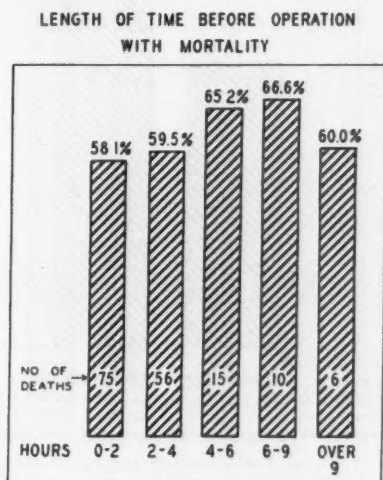
Chart 4. Graphic representation of mortality based on the lapse of time from receipt of injury until beginning of operation.

hours. What then was the cause of the delay, and what can be done to eliminate unnecessary loss of time?

The injured usually were brought to the emergency room within a few minutes of the shooting, so that most of the valuable time lost was due to poor management at the hospital. One of the causes of the delay was that the majority of the cases occurred at nights or on holidays when the efficiency of the personnel of the hospital was at the lowest ebb. Another factor that contributed to the delay was that the patient was usually first seen by an inexperienced intern who in most instances did not appreciate the degree of shock and the necessity for haste. He often allowed the patient to be questioned at length by the police, also too frequently he had the patient x-rayed in an attempt to find air under the diaphragm or to study the course of the bullet.

Preliminary x-ray examination may be of value in the determination of the possibility of questionable entrance into the abdominal cavity, but as a routine procedure should be discouraged because of the imposed preoperative delay and the added moving and handling of patients, most of whom are in an extreme degree of shock. Some of the other causes of delay were the lack of haste in admit-

THE VALUE OF TRANSFUSION
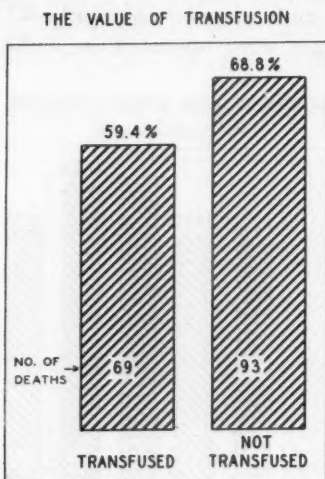
Chart 5. Graphic representation of mortality in those transfused.

tiny the patient, undressing and preparing for the operation, in notifying the resident surgeon, and, finally, in setting up the operating room for the exploration.

These faults may be overcome by notifying the resident surgeon the minute the patient arrives in the emergency room, by sending the patient directly to the operating room where he is treated for shock and operated on at the earliest possible moment.

Since it has been shown that hemorrhage is the greatest cause of shock and the greatest single factor in the determination of the mortality, it is imperative that these patients receive large amounts of blood immediately. However, in the past it has been a difficult task to find suitable donors in time to combat shock. This problem is now solved by the giving of plasma, both before and during the operation. The merits of plasma are too well known to be described; it is sufficient to say that plasma increases the blood volume to a level that permits these severely injured patients to be given the benefit of exploration.

One hundred sixteen cases were transfused either before, during, or following the operation, and this total was 34.4 per cent of the total number of cases. The mortality in the 116 cases receiving blood was 59.4 per cent as against a mortality of 68.8 per cent in the 135 cases in this group that did not receive blood (chart 5). The merits of blood in the treatment of gunshot wounds of the

DURATION OF OPERATION WITH MORTALITY
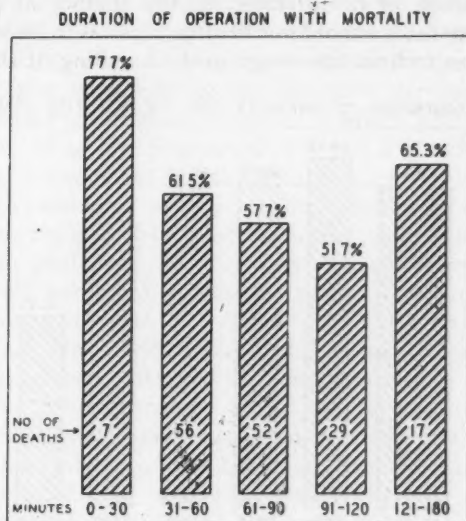
Chart 6. Graphic representation of the mortality based on a study of the duration of operation.

abdomen should not be questioned, for there was a lowering of the mortality of 9.5 per cent in those that were transfused and this percentage will be much higher when plasma is available to all of the hospitals.

Exploration should be done at the earliest possible moment, when it is felt that the patient has sufficiently recovered from shock to withstand an operation with a fair degree of safety. Experience has taught that hemorrhage must be controlled as soon as possible since blood loss is the chief cause of shock in gunshot wounds.

Deep surgical anesthesia is required since complete relaxation is necessary in order to examine completely and carefully all of the intestinal tract for perforations. In this series ether was the anesthetic chosen most often as it gave the required relaxation not associated with very much shock. There was a great temptation to use spinal anesthesia because of its great relaxing power, but this anesthetic was only occasionally used as it had a tendency to drop the

blood pressure, which in most cases was already at a dangerously low level. Local and gas anesthesia did not give the proper relaxation and made it necessary for the operator to fight the intestines, causing further shock and squeezing more material out into the peritoneal cavity.

When exploration has once been begun, regardless of the patient's condition, amount of hemorrhage, or the number of perforations to close, the operator should not become careless in his examination, too hasty in his technic, too rough in the handling of the intestines.

A COMPARISON OF MORTALITY FOR THE PAST FIVE YEARS
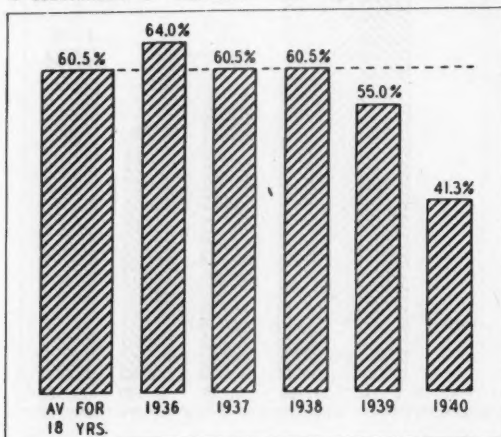
Chart 7. Graphic representation of a comparison of mortality for the past five years.

As paradoxical as it may seem, the mortality decreased in inverse proportion to the length of the operation. In the operation of less than thirty minutes the mortality was 77.7 per cent and the mortality was gradually reduced as the length of the operation increased until the lowest rate was between 91 and 120 minutes, when the mortality was 51.7 per cent (chart 6). After two hours the mortality again increased to 65.3 per cent and this probably can be explained by the fact that the operator was exceedingly slow or there was a great deal of damage to repair. The high mortality in the operative group requiring less than one hour can be explained by the fact that first, in most serious cases death occurred within 30 or 40 minutes. Secondly, the hasty or careless operator is more likely to overlook perforations, and it is not of much value in racing against time, trying to get the patient back to the ward alive, to close eight or ten perforations and leave one not closed. A study of the autopsy reports showed that 66.6 per cent of those perfor-

ations overlooked at the time of the operation occurred in those cases requiring less than one hour to complete the exploration. It should be emphasized, however, that slowness is not a virtue, but in an attempt to secure speed the operator should not sacrifice thoroughness.

In opening the abdomen a long muscle-splitting incision is advised so that all of the abdominal organs can be visualized. Also, the anesthesia should be of such a depth that when the peritoneum is incised abdominal packs are not necessary to restrain the intestines into the peritoneal cavity since fighting the intestines increases shock, promotes bleeding and squeezes intestinal contents out into the peritoneal cavity. If no bleeding vessel or organ is noted on superficial examination, a systematic examination is begun. First, the small intestines are examined as they are the most likely to be injured, also to contain the greatest number of perforations. If a perforation is seen in the small intestines before systematic search begins, the opening should be closed leaving the suture long with a hemostat attached so as to serve as a landmark. If no perforation is seen at first glance, the landmark should be established by placing a long suture with a hemostat attached in a bloodless area in the mesentery and then search both proximal and distal for perforations. This method prevents unnecessary manipulation of the intestines, squeezing out of the contents of the intestines, and the handling of the same portion of the gut twice that occurs when the operator uses either the ligament of Treitz or iliocecal junction as the landmark. Never, at any time, should the guts be delivered outside of the peritoneal cavity in order to aid in a search for injuries. Next, a systematic examination of the other organs is made.

Simple closure of the perforation is the best procedure, for any attempt at resection is associated with a high mortality. In this study, 36 cases required resection with a resulting mortality of 80.6 per cent. However, resection becomes necessary when a considerable portion of the gut is shot away, or when the blood supply to a section of gut is destroyed.

In case of severe damage to either spleen or kidney, removal was advised, other methods to control hemorrhage usually being unsuccessful. In case of large rents in the liver, no better method of controlling hemorrhage has been found than to pack with gauze, allowing the end to emerge from a stab wound so as to be removed at a later date.

When the operation is completed, it is advisable to aspirate from the peritoneal cavity all of the free blood that one possibly can, as the blood is mixed with intestinal contents and serves as a good culture medium.

It has been my practice for the last three years to place sulfanila-mide into the peritoneal cavity. At first, prontosil was used but lately 120 grains of sulfanilamide crystals are placed in 1,000 c.c. of sterile water, and just before the peritoneum is closed the fluid is poured into the abdominal cavity. After this the abdomen is closed tightly without drainage. The rapidity with which sulfanilamide has been absorbed from the peritoneal cavity has been proven by the concentration in the blood at intervals of twelve and twenty-four hours. At twelve hours the concentration ranges from 5 to 7 mg. and at twenty-four hours, ranges from 7 to 9 mg. Sulfanilamide medication is continued postoperatively to maintain a concentration in the blood of from 10 to 12 mg.

The advantage of using sulfanilamide in the peritoneal cavity is threefold; first, it has proven to be one of the quickest ways to get a sufficient concentration of the drug into the patient. Secondly, it has been proven that with the local absorption of this drug the concentration of sulfanilamide in the absorbing tissue is at a higher level than when given by other routes, and in this case the concentra-tion is in the peritoneal cavity, which will bear the brunt of the in-fection. Lastly, since the drug is in solution, it will come in contact with most of the peritoneal cavity and be mixed with any remain-ing intestinal content or blood, and although this drug is not bac-tericidal, research has proven that it retards the growth of patho-logic organisms.

Postoperatively the fluid level should be kept up by the daily ad-ministration of at least 2,500 c.c. of fluids under the skin or intra-venously, and 300 c.c. of this should be blood.

The efficiency of any method of treatment is the end results ob-tained. What improvement, if any, has been obtained in the results of the cases occurring in Nashville during the year 1940 as com-pared to the years preceding (chart 7). The general average of the seventeen years was 60.5 per cent, and for the last five years as follows:

CHART 8

1936	64 per cent
1937	60.5 per cent
1938	60.5 per cent
1939	55 per cent
1940	41.3 per cent

So that in the last year the mortality in the twenty-nine cases is 19.2 per cent lower than the general average, and this is a remark-able drop. This number of cases during 1940 is too small to prove anything definite, but it has given us encouragement to continue this plan of treatment in those cases of the future.

The Southern Surgeon

DR. WILLIS COHOON CAMPBELL

The career of a great pioneer orthopedic surgeon has come to a close. Willis Campbell is dead. Few men of the entire profession of our country have ever been so truly missed as he will be.

Willis Cohoon Campbell was born in Jackson, Mississippi, on December 18, 1880. His early education was received in public and private schools in Mississippi, and his college academic and pre-medical training at Hampden-Sydney College, Roanoke College and the University of Virginia. He was graduated from the University of Virginia Medical School in 1904, and following two years of internship, entered practice in Memphis. There, on June 30, 1908, he was married to Miss Elizabeth Yerger.

Being endowed with a rare power of vision, Dr. Campbell recognized early in his career a great and growing need for orthopedic surgeons, particularly in the Mid-South. He therefore determined to specialize in orthopedics, and to that end, in 1909, went to London, Vienna, New York and Boston for postgraduate study with the masters in this field. Thereafter, he resumed practice in Memphis, devoting himself exclusively to his specialty. In 1920, he built the clinic which bears his name, and which has since become the largest private institution of its kind in the world.

Soon after his return to Memphis, Dr. Campbell was invited to establish a Department of Orthopedic Surgery in the University of Tennessee. He did so, and throughout life served as Chief of the Department, developing it into one of the best in the country, and thus adding in no small masure to the prestige of the university.

One need only scan the list of honors conferred upon Dr. Campbell to appreciate his gift for organization and leadership. Among the official positions which he held in professional circles were the presidency of the Memphis and Shelby County Medical Society, in 1921; presidency of the Clinical Orthopaedic Society, in 1928; presidency of the American Orthopaedic Association, in 1931; presidency of the American Academy of Orthopedics, in 1933; and presidency of The Southeastern Surgical Congress, in 1933. He was also a member of the Board of Governors of the American College of Surgeons from 1936 to 1939; a member of the House of Delegates of the American Medical Association, in 1939 and 1940   Chairman of the American Board of Orthopaedic Surgery, in 1940; and a lifetime member of the Advisory Committee of the International Society for Crippled Children, and of the Advisory Board of the Georgia Warm Springs Foundation.

The list of Dr. Campbell's other professional affiliations included memberships in the International Society of Orthopaedic Surgeons, the Interurban Orthopaedic Club, Pan-American Medical Association, Southern Surgical Association, Southern Medical Association, Tennessee State Medical Association, and honorary memberships in several American and foreign societies. In addition, he was Consultant in Orthopedic Surgery for the Baptist Memorial Hospital, the Methodist, John Gaston, St. Joseph's and United States Marine Hospitals, and Chief of Staff of the Willis C. Campbell Clinic, the Crippled Children's Hospital, and the Hospital for Crippled Adults, all of Memphis.

Outside the profession, Dr. Campbell took an active part in the Episcopal Church and in the affairs of civic and social clubs and fraternities, with which he had extensive connections.

Of all the scientific organizations of which Dr. Campbell was a member, the one in which he was most absorbingly interested was the American Academy of Orthopaedic Surgeons, an institution dedicated to the purpose of providing the highest type of postgraduate training for orthopedists throughout the United States. His preference was pardonable, for it was he who conceived the idea of such an organization and who was chiefly responsible for its foundation. In recognition of his service, the Academy made him its first president, in 1933.

Dr. Campbell's capacity for work seemed almost superhuman. In addition to his numerous other activities, he was an indefatigable writer, his scientific articles being counted by the score. He was, moreover, the author of three books, the first, a monograph, "Orthopaedics of Childhood," published in 1927; the second, a textbook,

WILLIS COHOON CAMPBELL, M. D.
1880-1941
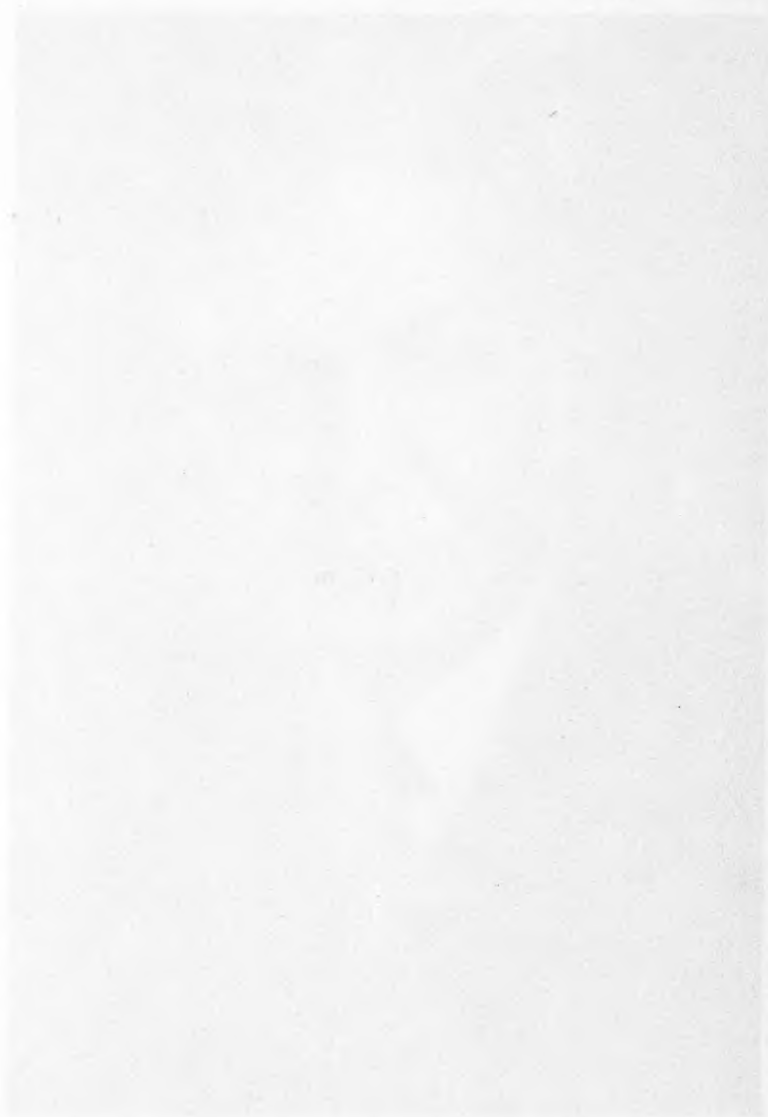
"Orthopaedic Surgery," published in 1930 and still widely used in medical colleges over the country; and the third, Operative Ortho-paedics," a comprehensive volume on current operative technic, pub-lished in 1939. In the field of surgery itself, he was no less active, having devised more than a dozen operations for various ortho-pedic conditions, many of which have been universally adopted as standard procedures.

Certainly, no man has ever loved his profession more. He strove unceasingly to elevate the standards of orthopedic surgery, to im-prove its technic, and to train young men in the perfection of its science and art. His ideals were given concrete expression in his clinic, which, as a consequence, become a Mecca for prospective orthopedic surgeons in search of the newest and best in their chosen field.

Though wide his influence and well deserved his honors, they were not the things for which Willis Campbell was most loved and esteemed in his native Mid-South. His own people will always re-member him best for his boundless humanitarianism. The Crippled Children's Hospital and the Hospital for Crippled Adults, which he was largely instrumental in establishing and whose growth he helped to direct, stand as splendid memorials to his beneficence. For within those institutions, during the past twenty years, thou-sands of afflicted and helpless human beings have been restored to health and usefulness through his generosity.

It was the author's privilege to have known Willis for more than two decades and to have enjoyed his companionship on many oc-casions. To know him was to love him, for his magnetic charm, his sincerity, his strong sense of fairness, and his unfailing kindness and courtesy endeared him to all who came within his ken. Indeed, only a little with him, and one was convinced that here, undisputably, was greatness.

Death came to Dr. Campbell in Chicago, on May 4, 1941. He had been stricken with a heart ailment a year before, and this, com-plicated by pneumonia, brought about his last illness. Surviving him are his wife and four children.

We of The Southeastern Surgical Congress are keenly mindful of the fact that one of our most distinguished and distinguishing members will grace our gatherings no more. In life, we honored Dr. Campbell with the presidency of the Congress; in death, we honor him with a deep and sorrowful sense of loss, not only to the Congress, but, most of all, to ourselves.

—R. L. SANDERS.